L Number	Hits	Search Text	DB	Time stamp
-	1	wavelet and randon	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:19
-	1	randon near2 transform	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	2	randon and (neural near network)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	567	randon	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	81	wavelet and backpropagation	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	2856	wavelet near2 transform$4	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	33	(wavelet and backpropagation) and (wavelet near2 transform$4)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:54
-	73	(706/22).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:23
-	2596	wavelet adj transform$4	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:54
-	0	randon and (wavelet adj transform$4)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:54
-	31	(wavelet adj transform$4) and backpropagation	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	350	radon near2 transform	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	32	radon and (neural near network)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	3171	radon	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50

-	81	wavelet and backpropagation	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	2856	wavelet near2 transform$4	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:50
-	2596	wavelet adj transform$4	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:51
-	3	gindikin	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:51
-	61	bolker	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:51
-	2	gindikin and bolker	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:51
-	33	(wavelet and backpropagation) and (wavelet near2 transform$4)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:54
-	2596	wavelet adj transform$4	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:54
-	21	radon and (wavelet adj transform$4)	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	31	(wavelet adj transform$4) and backpropagation	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	254	(382/156).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	474	(382/276).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	1289	(382/232).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:55
-	452	(382/240).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:56

	73	(706/22).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:56
–	450	(706/20).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:56
–	63	(706/19).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:56
–	240	(706/15).CCLS.	USPAT; US-PGPUB; EPO; JPO; DERWENT; IBM_TDB	2003/09/28 10:57

◈IEEE

Membership   Publications/Services   Standards   Conferences   Careers/Jobs

IEEE *Xplore*®
RELEASE 1.4

Welcome
United States Patent and Trademark Office

Help   FAQ   Terms   IEEE Peer
Review

Quick Links   ▫

» **Search Results**

Welcome to IEEE *Xplore*

○ Home
○ What Can
    I Access?
○ Log-out

Tables of Contents

○ Journals
    & Magazines
○ Conference
    Proceedings
○ Standards

Search

○ By Author
○ Basic
○ Advanced

Member Services

○ Join IEEE
○ Establish IEEE
    Web Account
○ Access the
    IEEE Member
    Digital Library

🖶 Print Format

Your search matched **2** of **972916** documents.
Results are shown **15** to a page, sorted by **publication year** in **descending** order.

Results:
Journal or Magazine = **JNL**   Conference = **CNF**   Standard = **STD**

---

1 **Semantics of multimedia in MPEG-7**
*Benitez, A.B.; Rising, H.; Jorgensen, C.; Leonardi, R.; Bugatti, A.; Hasida, K.;
Mehrotra, R.; Murat Tekalp, A.; Ekin, A.; Walker, T.;*
Image Processing. 2002. Proceedings. 2002 International Conference on ,
Volume: 1 , 22-25 Sept. 2002
Page(s): I-137 -I-140 vol.1

[Abstract]   [PDF Full-Text (377 KB)] **IEEE CNF**

---

2 **Video compression by mean-corrected motion compensation of partial
quadtrees** ˙
*Calzone, S.; Chen, K.; Chih-Chwen Chuang; Divakaran, A.; Dube, S.; Hurd, L.;
Kari, J.; Liang, G.; Fu-Huei Lin; Muller, J.; Rising, H.K., III.;*
Circuits and Systems for Video Technology, IEEE Transactions on , Volume: 7
Issue: 1 , Feb. 1997
Page(s): 86 -96

[Abstract]   [PDF Full-Text (488 KB)] **IEEE JNL**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

(1) .

Membership Publications/Services Standards Conferences Careers/Jobs

IEEE *Xplore®*
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Help FAQ Terms IEEE Peer Review **Quick Links** **» Search Results**

Welcome to IEEE Xplore

- Home
- What Can I Access?
- Log-out

Tables of Contents

- Journals & Magazines
- Conference Proceedings
- Standards

Search

- By Author
- Basic
- Advanced

Member Services

- Join IEEE
- Establish IEEE Web Account
- Access the IEEE Member Digital Library

Print Format

Your search matched **95** of **971113** documents.

A maximum of **95** results are displayed, 25 to a page, sorted by **Relevance** in **descending** order.
You may refine your search by editing the current search expression or entering a new one the text box.
Then click **Search Again**.

(wavelet and backpropagation) Search Again

Results:
Journal or Magazine = **JNL** Conference = **CNF** Standard = **STD**

---

1 Neural networks for ultrasonic NDE signal classification using time-frequency analysis
Chen, C.H.; Lee, G.G.;
Acoustics, Speech, and Signal Processing, 1993. ICASSP-93., 1993 IEEE International Conference on , Volume: 1 , 27-30 April 1993
Page(s): 493 -496 vol.1

[Abstract] [PDF Full-Text (232 KB)] **IEEE CNF**

---

2 Neural networks and wavelet analysis in the computer interpretation of pulse oximetry data
Dowla, F.U.; Skokowski, P.G.; Leach, R.R., Jr.;
Neural Networks for Signal Processing [1996] VI. Proceedings of the 1996 IEEE Signal Processing Society Workshop , 4-6 Sept. 1996
Page(s): 527 -536

[Abstract] [PDF Full-Text (380 KB)] **IEEE CNF**

---

3 Neural-network based analog-circuit fault diagnosis using wavelet transform as preprocessor
Aminian, M.; Aminian, F.;
Circuits and Systems II: Analog and Digital Signal Processing, IEEE Transactions on , Volume: 47 Issue: 2 , Feb. 2000
Page(s): 151 -156

[Abstract] [PDF Full-Text (144 KB)] **IEEE JNL**

---

4 Neural network detection of small moving radar targets in an ocean environment
Cunningham, J.; Haykin, S.;
Neural Networks for Signal Processing [1992] II., Proceedings of the 1992 IEEE-SP Workshop , 31 Aug.-2 Sept. 1992
Page(s): 306 -315

[Abstract] [PDF Full-Text (380 KB)] **IEEE CNF**

---

5 Learning approaches in motion control using neural networks
Sanchez A., V.D.;
Motion Control Proceedings, 1993., Asia-Pacific Workshop on Advances in , 15-16 July 1993
Page(s): 75

[Abstract] [PDF Full-Text (44 KB)] **IEEE CNF**

---

6 Recurrent wavelet networks
Rao, S.S.; Kumthekar, B.;
Neural Networks, 1994. IEEE World Congress on Computational Intelligence., 1994 IEEE International Conference on , Volume: 5 , 27 June-2 July 1994

Page(s): 3143 -3147 vol.5

[Abstract] [PDF Full-Text (316 KB)] **IEEE CNF**

---

7 **Using wavelets in nonparametric estimation**
Zhang, Q.;
Decision and Control, 1994., Proceedings of the 33rd IEEE Conference on ,
Volume: 4 , 14-16 Dec. 1994
Page(s): 3406 -3411 vol.4

[Abstract] [PDF Full-Text (396 KB)] **IEEE CNF**

---

8 **Comparing wavelet transforms and AR modeling as feature extraction tools for underwater signal classification**
Fargues, M.P.; Bennett, R.;
Signals, Systems and Computers, 1995. 1995 Conference Record of the
Twenty-Ninth Asilomar Conference on , Volume: 2 , 30 Oct.-2 Nov. 1995
Page(s): 915 -919 vol.2

[Abstract] [PDF Full-Text (748 KB)] **IEEE CNF**

---

9 **ScaleNet-multiscale neural network architecture for time series prediction**
Geva, A.B.; Altman, A.K.;
Electrical and Electronics Engineers in Israel, 1996., Nineteenth Convention of ,
5-6 Nov. 1996
Page(s): 243 -246

[Abstract] [PDF Full-Text (372 KB)] **IEEE CNF**

---

10 **Multiresolution wavelet analysis based feature extraction for neural network classification**
Chen, C.H.; Lee, G.G.;
Neural Networks, 1996., IEEE International Conference on , Volume: 3 , 3-6 June
1996
Page(s): 1416 -1421 vol.3

[Abstract] [PDF Full-Text (500 KB)] **IEEE CNF**

---

11 **Detection of epileptiform activity using wavelet and neural network**
Park, H.S.; Lee, Y.H.; Lee, D.S.; Kim, S.I.;
Engineering in Medicine and Biology society, 1997. Proceedings of the 19th
Annual International Conference of the IEEE , Volume: 3 , 30 Oct.-2 Nov. 1997
Page(s): 1194 -1197 vol.3

[Abstract] [PDF Full-Text (316 KB)] **IEEE CNF**

---

12 **Classification of EEG signals using the wavelet transform**
Hazarika, N.; Chen, J.Z.; Ah Chung Tsoi; Sergejew, A.;
Digital Signal Processing Proceedings, 1997. DSP 97., 1997 13th International
Conference on , Volume: 1 , 2-4 July 1997
Page(s): 89 -92 vol.1

[Abstract] [PDF Full-Text (340 KB)] **IEEE CNF**

---

13 **Selection of parameters from power spectral density, wavelet transforms and other methods for the automated interpretation of the ECG**
Celler, B.; de Chazal, P.;
Digital Signal Processing Proceedings, 1997. DSP 97., 1997 13th International
Conference on , Volume: 1 , 2-4 July 1997
Page(s): 71 -74 vol.1

[Abstract] [PDF Full-Text (428 KB)] **IEEE CNF**

14 Automatic detection of epileptiform activity using wavelet and expert rule base
Kim, S.B.; Lee, Y.H.; Kim, J.H.; Kim, S.I.;
Engineering in Medicine and Biology Society, 1998. Proceedings of the 20th Annual International Conference of the IEEE , Volume: 4 , 29 Oct.-1 Nov. 1998
Page(s): 2078 -2081 vol.4

[Abstract] [PDF Full-Text (232 KB)] **IEEE CNF**

15 Underwater target classification using wavelet packets and neural networks
Qiang Huang; Azimi-Sadjadi, M.R.; Bin Tian; Dobeck, G.;
Neural Networks Proceedings, 1998. IEEE World Congress on Computational Intelligence. The 1998 IEEE International Joint Conference on , Volume: 1 , 4-9 May 1998
Page(s): 177 -182 vol.1

[Abstract] [PDF Full-Text (596 KB)] **IEEE CNF**

16 Neural wavelet analysis of life threatening ventricular arrhythmias
Khadra, L.; Abdallah, M.; Nashash, H.;
Southeastcon '98. Proceedings. IEEE , 24-26 April 1998
Page(s): 228 -229

[Abstract] [PDF Full-Text (120 KB)] **IEEE CNF**

17 An EMG classification method based on wavelet transform [and ANN]
Liyu Cai; Zhizhong Wang; Haihong Zhang;
[Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint , Volume: 1 , 13-16 Oct. 1999
Page(s): 565 vol.1

[Abstract] [PDF Full-Text (108 KB)] **IEEE CNF**

18 Detection of VPC using wavelet transform and fuzzy neural network
Ying-Hsuan Wu; Liang-Yu Shyu;
[Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference, 1999. Proceedings of the First Joint , Volume: 2 , 13-16 Oct. 1999
Page(s): 1200 vol.2

[Abstract] [PDF Full-Text (60 KB)] **IEEE CNF**

19 Radar object recognition by wavelet transform and neural network
Tkac, J.; Spirko, S.; Boka, L.;
Microwaves, Radar and Wireless Communications. 2000. MIKON-2000. 13th International Conference on , Volume: 1 , 22-24 May 2000
Page(s): 239 -243 vol.1

[Abstract] [PDF Full-Text (236 KB)] **IEEE CNF**

20 Dynamic wavelet neural network for nonlinear dynamic system identification
Yonghong Tan; Xuanju Dang; Feng Liang; Chun-Yi Su;
Control Applications, 2000. Proceedings of the 2000 IEEE International Conference on , 25-27 Sept. 2000
Page(s): 214 -219

[Abstract] [PDF Full-Text (420 KB)] **IEEE CNF**

21 **Using neural networks with wavelet transforms for an automated mammographic mass classifier**
Bruce, L.M.; Shanmugam, N.;
Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE , Volume: 2 , 23-28 July 2000
Page(s): 985 -987 vol.2

[Abstract] [PDF Full-Text (216 KB)] **IEEE CNF**

22 **Short term load forecasting by using wavelet neural networks**
Bashir, Z.; El-Hawary, M.E.;
Electrical and Computer Engineering, 2000 Canadian Conference on , Volume: 1 ,
7-10 March 2000
Page(s): 163 -166 vol.1

[Abstract] [PDF Full-Text (272 KB)] **IEEE CNF**

23 **On-line handwritten signature verification using wavelets and back-propagation neural networks**
Lejtman, D.Z.; George, S.E.;
Document Analysis and Recognition, 2001. Proceedings. Sixth International Conference on , 10-13 Sept. 2001
Page(s): 992 -996

[Abstract] [PDF Full-Text (344 KB)] **IEEE CNF**

24 **A technique based on wavelet and morphology transform to recognize the cancer cell in pleural effusion**
Fuhua Chen; Jun Xie; Hong Zhang; Deshen Xia;
Medical Imaging and Augmented Reality, 2001. Proceedings. International Workshop on , 10-12 June 2001
Page(s): 199 -203

[Abstract] [PDF Full-Text (324 KB)] **IEEE CNF**

25 **Ipsilateral multi-view CAD system for mass detection in digital mammography**
Xuejun Sun; Wei Qian; Dansheng Song; Robert, A.C.;
Mathematical Methods in Biomedical Image Analysis, 2001. MMBIA 2001. IEEE Workshop on , 9-10 Dec. 2001
Page(s): 19 -26

[Abstract] [PDF Full-Text (948 KB)] **IEEE CNF**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

◆IEEE

IEEE Xplore®
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Help FAQ Terms IEEE Peer
Review

Quick Links   [·]

» Search Results

Welcome to IEEE Xplore⁺

O- Home
O- What Can
   I Access?
O- Log-out

Tables of Contents

O- Journals
   & Magazines
O- Conference
   Proceedings
O- Standards

Search

O- By Author
O- Basic
O- Advanced

Member Services

O- Join IEEE
O- Establish IEEE
   Web Account

O- Access the
   IEEE Member
   Digital Library

⊟ Print Format

Your search matched **84** of **972916** documents.

A maximum of **84** results are displayed, **25** to a page, sorted by **Relevance** in **descending** order.
You may refine your search by editing the current search expression or entering a new one the text box.
Then click **Search Again**.

(wavelet and backpropagation) and (transform) | Search Again |

Results:
Journal or Magazine = **JNL** Conference = **CNF** Standard = **STD**

1 **Neural network detection of small moving radar targets in an ocean environment**
Cunningham, J.; Haykin, S.;
Neural Networks for Signal Processing [1992] II., Proceedings of the 1992
IEEE-SP Workshop , 31 Aug.-2 Sept. 1992
Page(s): 306 -315

[Abstract] [PDF Full-Text (380 KB)] **IEEE CNF**

2 **Comparing wavelet transforms and AR modeling as feature extraction tools for underwater signal classification**
Fargues, M.P.; Bennett, R.;
Signals, Systems and Computers, 1995. 1995 Conference Record of the
Twenty-Ninth Asilomar Conference on , Volume: 2 , 30 Oct.-2 Nov. 1995
Page(s): 915 -919 vol.2

[Abstract] [PDF Full-Text (748 KB)] **IEEE CNF**

3 **Classification of EEG signals using the wavelet transform**
Hazarika, N.; Chen, J.Z.; Ah Chung Tsoi; Sergejew, A.;
Digital Signal Processing Proceedings, 1997. DSP 97., 1997 13th International
Conference on , Volume: 1 , 2-4 July 1997
Page(s): 89 -92 vol.1

[Abstract] [PDF Full-Text (340 KB)] **IEEE CNF**

4 **Selection of parameters from power spectral density, wavelet transforms and other methods for the automated interpretation of the ECG**
Celler, B.; de Chazal, P.;
Digital Signal Processing Proceedings, 1997. DSP 97., 1997 13th International
Conference on , Volume: 1 , 2-4 July 1997
Page(s): 71 -74 vol.1

[Abstract] [PDF Full-Text (428 KB)] **IEEE CNF**

5 **Automatic detection of epileptiform activity using wavelet and expert rule base**
Kim, S.B.; Lee, Y.H.; Kim, J.H.; Kim, S.I.;
Engineering in Medicine and Biology Society, 1998. Proceedings of the 20th
Annual International Conference of the IEEE , Volume: 4 , 29 Oct.-1 Nov. 1998
Page(s): 2078 -2081 vol.4

[Abstract] [PDF Full-Text (232 KB)] **IEEE CNF**

6 **An EMG classification method based on wavelet transform [and ANN]**
Liyu Cai; Zhizhong Wang; Haihong Zhang;
[Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999
Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference,
1999. Proceedings of the First Joint , Volume: 1 , 13-16 Oct. 1999
Page(s): 565 vol.1

[Abstract] [PDF Full-Text (108 KB)] **IEEE CNF**

7 **Detection of VPC using wavelet transform and fuzzy neural network**
Ying-Hsuan Wu; Liang-Yu Shyu;
[Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999
Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference,
1999. Proceedings of the First Joint , Volume: 2 , 13-16 Oct. 1999
Page(s): 1200 vol.2

[Abstract] [PDF Full-Text (60 KB)] **IEEE CNF**

8 **Radar object recognition by wavelet transform and neural network**
Tkac, J.; Spirko, S.; Boka, L.;
Microwaves, Radar and Wireless Communications. 2000. MIKON-2000. 13th
International Conference on , Volume: 1 , 22-24 May 2000
Page(s): 239 -243 vol.1

[Abstract] [PDF Full-Text (236 KB)] **IEEE CNF**

9 **Using neural networks with wavelet transforms for an automated
mammographic mass classifier**
Bruce, L.M.; Shanmugam, N.;
Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd
Annual International Conference of the IEEE , Volume: 2 , 23-28 July 2000
Page(s): 985 -987 vol.2

[Abstract] [PDF Full-Text (216 KB)] **IEEE CNF**

10 **On-line handwritten signature verification using wavelets and
back-propagation neural networks**
Lejtman, D.Z.; George, S.E.;
Document Analysis and Recognition, 2001. Proceedings. Sixth International
Conference on , 10-13 Sept. 2001
Page(s): 992 -996

[Abstract] [PDF Full-Text (344 KB)] **IEEE CNF**

11 **Ipsilateral multi-view CAD system for mass detection in digital
mammography**
Xuejun Sun; Wei Qian; Dansheng Song; Robert, A.C.;
Mathematical Methods in Biomedical Image Analysis, 2001. MMBIA 2001. IEEE
Workshop on , 9-10 Dec. 2001
Page(s): 19 -26

[Abstract] [PDF Full-Text (948 KB)] **IEEE CNF**

12 **Analysis of neural networks for face recognition systems with feature
extraction to develop an eye localization based method**
Rizk, M.R.M.; Taha, A.;
Electronics, Circuits and Systems, 2002. 9th International Conference on ,
Volume: 3 , 15-18 Sept. 2002
Page(s): 847 -850 vol.3

[Abstract] [PDF Full-Text (326 KB)] **IEEE CNF**

13 **Feature extraction with wavelet transform for recognition of isolated
handwritten Farsi/Arabic characters and numerals**
Mowlaei, A.; Faez, K.; Haghighat, A.T.;
Digital Signal Processing, 2002. DSP 2002. 2002 14th International Conference

on , Volume: 2 , 1-3 July 2002
Page(s): 923 -926 vol.2

[Abstract] [PDF Full-Text (333 KB)] **IEEE CNF**

---

14 **Wavelet networks**
Zhang, Q.; Benveniste, A.;
Neural Networks, IEEE Transactions on , Volume: 3 Issue: 6 , Nov. 1992
Page(s): 889 -898

[Abstract] [PDF Full-Text (800 KB)] **IEEE JNL**

---

15 **New fault diagnosis of circuit breakers**
Lee, D.S.S.; Lithgow, B.J.; Morrison, R.E.;
Power Delivery, IEEE Transactions on , Volume: 18 Issue: 2 , April 2003
Page(s): 454 -459

[Abstract] [PDF Full-Text (292 KB)] **IEEE JNL**

---

16 **ScaleNet-multiscale neural network architecture for time series prediction**
Geva, A.B.; Altman, A.K.;
Electrical and Electronics Engineers in Israel, 1996., Nineteenth Convention of ,
5-6 Nov. 1996
Page(s): 243 -246

[Abstract] [PDF Full-Text (372 KB)] **IEEE CNF**

---

17 **Detection of epileptiform activity using wavelet and neural network**
Park, H.S.; Lee, Y.H.; Lee, D.S.; Kim, S.I.;
Engineering in Medicine and Biology society, 1997. Proceedings of the 19th
Annual International Conference of the IEEE , Volume: 3 , 30 Oct.-2 Nov. 1997
Page(s): 1194 -1197 vol.3

[Abstract] [PDF Full-Text (316 KB)] **IEEE CNF**

---

18 **Neural wavelet analysis of life threatening ventricular arrhythmias**
Khadra, L.; Abdallah, M.; Nashash, H.;
Southeastcon '98. Proceedings. IEEE , 24-26 April 1998
Page(s): 228 -229

[Abstract] [PDF Full-Text (120 KB)] **IEEE CNF**

---

19 **A technique based on wavelet and morphology transform to recognize the cancer cell in pleural effusion**
Fuhua Chen; Jun Xie; Hong Zhang; Deshen Xia;
Medical Imaging and Augmented Reality, 2001. Proceedings. International
Workshop on , 10-12 June 2001
Page(s): 199 -203

[Abstract] [PDF Full-Text (324 KB)] **IEEE CNF**

---

20 **Neural-network based analog-circuit fault diagnosis using wavelet transform as preprocessor**
Aminian, M.; Aminian, F.;
Circuits and Systems II: Analog and Digital Signal Processing, IEEE Transactions
on , Volume: 47 Issue: 2 , Feb. 2000
Page(s): 151 -156

[Abstract] [PDF Full-Text (144 KB)] **IEEE JNL**

---

21 Neural network technology for image compression
Jiang, J.;
Broadcasting Convention, 1995. IBC 95., International , 14-18 Sep 1995
Page(s): 250 -257

[Abstract] [PDF Full-Text (496 KB)] **IEE CNF**

22 Optoelectronic fractal scanning technique for wavelet transform and neural net pattern classifiers
Phuvan, S.; Oh, T.K.; Caviris, N.; Li, Y.; Szu, H.;
Neural Networks, 1992. IJCNN., International Joint Conference on , Volume: 1 ,
7-11 June 1992
Page(s): 40 -46 vol.1

[Abstract] [PDF Full-Text (440 KB)] **IEEE CNF**

23 Neural networks for ultrasonic NDE signal classification using time-frequency analysis
Chen, C.H.; Lee, G.G.;
Acoustics, Speech, and Signal Processing, 1993. ICASSP-93., 1993 IEEE
International Conference on , Volume: 1 , 27-30 April 1993
Page(s): 493 -496 vol.1

[Abstract] [PDF Full-Text (232 KB)] **IEEE CNF**

24 Learning approaches in motion control using neural networks
Sanchez A., V.D.;
Motion Control Proceedings, 1993., Asia-Pacific Workshop on Advances in , 15-16
July 1993
Page(s): 75

[Abstract] [PDF Full-Text (44 KB)] **IEEE CNF**

25 Transformation of back-propagation networks in multiresolution learning
Wing-Chung Chan; Lai-Wan Chan;
Neural Networks, 1994. IEEE World Congress on Computational Intelligence.,
1994 IEEE International Conference on , Volume: 1 , 27 June-2 July 1994
Page(s): 290 -294 vol.1

[Abstract] [PDF Full-Text (416 KB)] **IEEE CNF**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

IEEE HOME I SEARCH IEEE I SHOP I WEB ACCOUNT I CONTACT IEEE   ◈IEEE

Membership Publications/Services Standards Conferences Careers/Jobs

IEEE *Xplore®*
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Help FAQ Terms IEEE Peer   **Quick Links**   » **Search Results**
Review

Welcome to IEEE *Xplore*

○ Home
○ What Can I Access?
○ Log-out

Tables of Contents

○ Journals & Magazines
○ Conference Proceedings
○ Standards

Search

○ By Author
○ Basic
○ Advanced

Member Services

○ Join IEEE
○ Establish IEEE Web Account
○ Access the IEEE Member Digital Library

🖶 Print Format

Your search matched **1** of **972916** documents.

A maximum of **1** results are displayed, **25** to a page, sorted by **Relevance** in **descending** order. You may refine your search by editing the current search expression or entering a new one the text box.

Then click **Search Again**.

[(wavelet <near> transform) and (backpropagation a] [Search Again]

Results:
Journal or Magazine = **JNL**   Conference = **CNF**   Standard = **STD**

1 **Analysis of neural networks for face recognition systems with feature extraction to develop an eye localization based method**
Rizk, M.R.M.; Taha, A.;
Electronics, Circuits and Systems, 2002. 9th International Conference on ,
Volume: 3 , 15-18 Sept. 2002
Page(s): 847 -850 vol.3

[Abstract] [PDF Full-Text (326 KB)] **IEEE CNF**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

IEEE Xplore®
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Quick Links

» Search Results

Welcome to IEEE Xplore*

O- Home
O- What Can I Access?
O- Log-out

Tables of Contents

O- Journals & Magazines
O- Conference Proceedings
O- Standards

Search

O- By Author
O- Basic
O- Advanced

Member Services

O- Join IEEE
O- Establish IEEE Web Account
O- Access the IEEE Member Digital Library

🖨 Print Format

Your search matched **37** of **972916** documents.

A maximum of **37** results are displayed, **25** to a page, sorted by **Relevance** in descending order.
You may refine your search by editing the current search expression or entering a new one the text box.
Then click **Search Again**.

(wavelet and radon)   Search Again

Results:
Journal or Magazine = **JNL**   Conference = **CNF**   Standard = **STD**

1 **The wavelet transform of higher dimension and the Radon transform**
Tai Chiu Hsung; Lun, D.P.K.;
Acoustics, Speech, and Signal Processing, 1995. ICASSP-95., 1995 International Conference on , Volume: 2 , 9-12 May 1995
Page(s): 1113 -1116 vol.2

[Abstract]   [PDF Full-Text (548 KB)] **IEEE CNF**

2 **Wavelet methods for inverting the Radon transform with noisy data**
Nam-Yong Lee; Lucier, B.J.;
Image Processing, IEEE Transactions on , Volume: 10 Issue: 1 , Jan. 2001
Page(s): 79 -94

[Abstract]   [PDF Full-Text (584 KB)] **IEEE JNL**

3 **Local tomography using wavelets**
Berenstein, C.; Walnut, D.;
Engineering in Medicine and Biology Society, 1994. Engineering Advances: New Opportunities for Biomedical Engineers. Proceedings of the 16th Annual International Conference of the IEEE , 3-6 Nov. 1994
Page(s): A6 -A7 vol.1

[Abstract]   [PDF Full-Text (108 KB)] **IEEE CNF**

4 **A wavelet localized Radon transform based detector for a signal with unknown parameters**
Warrick, A.L.; Delaney, P.A.;
Signals, Systems and Computers, 1995. 1995 Conference Record of the Twenty-Ninth Asilomar Conference on , Volume: 2 , 30 Oct.-2 Nov. 1995
Page(s): 860 -864 vol.2

[Abstract]   [PDF Full-Text (428 KB)] **IEEE CNF**

5 **Region-of-interest tomography using the wavelet transform and angular harmonics**
Yagle, A.E.;
Image Processing, 1995. Proceedings., International Conference on , Volume: 2 , 23-26 Oct. 1995
Page(s): 461 -463 vol.2

[Abstract]   [PDF Full-Text (236 KB)] **IEEE CNF**

6 **Detection of linear features using a localized Radon transform with a wavelet filter**
Warrick, A.L.; Delaney, P.A.;
Acoustics, Speech, and Signal Processing, 1997. ICASSP-97., 1997 IEEE International Conference on , Volume: 4 , 21-24 April 1997

14 **Wavelet-based multiresolution local tomography**
Rashid-Farrokhi, F.; Liu, K.J.R.; Berenstein, C.A.; Walnut, D.;
Image Processing, IEEE Transactions on , Volume: 6 Issue: 10 , Oct. 1997
Page(s): 1412 -1430

[Abstract] [PDF Full-Text (1260 KB)] **IEEE JNL**

15 **The curvelet transform for image denoising** .
Jean-Luc Starck; Candes, E.J.; Donoho, D.L.;
Image Processing, IEEE Transactions on , Volume: 11 Issue: 6 , June 2002
Page(s): 670 -684

[Abstract] [PDF Full-Text (459 KB)] **IEEE JNL**

16 **Wavelet localization of the Radon transform in even dimensions**
DeStefano, J.; Olson, T.;
Time-Frequency and Time-Scale Analysis, 1992., Proceedings of the IEEE-SP
International Symposium , 4-6 Oct. 1992
Page(s): 137 -140

[Abstract] [PDF Full-Text (284 KB)] **IEEE CNF**

17 **Local vector tomography by use of wavelets**
Strahlen, K.;
Image Processing, 2000. Proceedings. 2000 International Conference on ,
Volume: 2 , 10-13 Sept. 2000
Page(s): 617 -620 vol.2

[Abstract] [PDF Full-Text (292 KB)] **IEEE CNF**

18 **Wavelet localization of the Radon transform**
Olson, T.; DeStefano, J.;
Signal Processing, IEEE Transactions on [see also Acoustics, Speech, and Signal
Processing, IEEE Transactions on] , Volume: 42 Issue: 8 , Aug. 1994
Page(s): 2055 -2067

[Abstract] [PDF Full-Text (1100 KB)] **IEEE JNL**

19 **Iterative inversion of the Radon transform using image-adaptive
wavelet constraints**
Sahiner, B.; Yagle, A.E.;
Image Processing, 1998. ICIP 98. Proceedings. 1998 International Conference on
, Volume: 2 , 4-7 Oct. 1998
Page(s): 709 -713 vol.2

[Abstract] [PDF Full-Text (432 KB)] **IEEE CNF**

20 **Determination of a segment endpoint by means of the Radon
transform**
Olmo, G.; Magli, E.;
Electronics, Circuits and Systems, 1999. Proceedings of ICECS '99. The 6th IEEE
International Conference on , Volume: 2 , 5-8 Sept. 1999
Page(s): 851 -854 vol.2

[Abstract] [PDF Full-Text (340 KB)] **IEEE CNF**

21 **Feature extraction of intra-pulse modulated signals using
time-frequency analysis**
Moraitakis, I.; Fargues, M.P.;
MILCOM 2000. 21st Century Military Communications Conference Proceedings ,
Volume: 2 , 22-25 Oct. 2000
Page(s): 737 -741 vol.2

[Abstract] [PDF Full-Text (440 KB)] **IEEE CNF**

---

22 Analysis of neural networks for face recognition systems with feature extraction to develop an eye localization based method
Rizk, M.R.M.; Taha, A.;
Electronics, Circuits and Systems, 2002. 9th International Conference on ,
Volume: 3 , 15-18 Sept. 2002
Page(s): 847 -850 vol.3

[Abstract] [PDF Full-Text (326 KB)] **IEEE CNF**

---

23 An algorithm for successive identification of reflections
Hansen, K.V.; Larsen, J.;
Image Processing, IEEE Transactions on , Volume: 3 Issue: 3 , May 1994
Page(s): 281 -291

[Abstract] [PDF Full-Text (892 KB)] **IEEE JNL**

---

24 On-board selection of relevant images: an application to linear feature recognition
Magli, E.; Olmo, G.; Lo Presti, L.;
Image Processing, IEEE Transactions on , Volume: 10 Issue: 4 , April 2001
Page(s): 543 -553

[Abstract] [PDF Full-Text (192 KB)] **IEEE JNL**

---

25 Regularization in tomographic reconstruction using thresholding estimators
Kalifa, J.; Laine, A.; Esser, P.D.;
Medical Imaging, IEEE Transactions on , Volume: 22 Issue: 3 , March 2003
Page(s): 351 -359

[Abstract] [PDF Full-Text (687 KB)] **IEEE JNL**

---

1 2 [Next]

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

IEEE HOME I SEARCH IEEE I SHOP I WEB ACCOUNT I CONTACT IEEE   ◆IEEE

Membership Publications/Services Standards Conferences Careers/Jobs

IEEE Xplore®
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Help   FAQ   Terms   IEEE Peer | **Quick Links** _____ [o]   » **Search Results**
Review

Welcome to IEEE Xplore*

O- Home
O- What Can
   I Access?
O- Log-out

Tables of Contents

O- Journals
   & Magazines
O- Conference
   Proceedings
O- Standards

Search

O- By Author
O- Basic
O- Advanced

Member Services

O- Join IEEE
O- Establish IEEE
   Web Account
O- Access the
   IEEE Member
   Digital Library

🖨 Print Format

Your search matched **37** of **972916** documents.

A maximum of **37** results are displayed, **25** to a page, sorted by **Relevance** in descending order.
You may refine your search by editing the current search expression or entering a new one the text box.
Then click **Search Again**.

(wavelet) and (radon and transform)   [Search Again]

Results:
Journal or Magazine = **JNL**   Conference = **CNF**   Standard = **STD**

1 **The wavelet transform of higher dimension and the Radon transform**
Tai Chiu Hsung; Lun, D.P.K.;
Acoustics, Speech, and Signal Processing, 1995. ICASSP-95., 1995 International
Conference on , Volume: 2 , 9-12 May 1995
Page(s): 1113 -1116 vol.2

[Abstract]   [PDF Full-Text (548 KB)] **IEEE CNF**

2 **Wavelet methods for inverting the Radon transform with noisy data**
Nam-Yong Lee; Lucier, B.J.;
Image Processing, IEEE Transactions on , Volume: 10 Issue: 1 , Jan. 2001
Page(s): 79 -94

[Abstract]   [PDF Full-Text (584 KB)] **IEEE JNL**

3 **Local tomography using wavelets**
Berenstein, C.; Walnut, D.;
Engineering in Medicine and Biology Society, 1994. Engineering Advances: New
Opportunities for Biomedical Engineers. Proceedings of the 16th Annual
International Conference of the IEEE , 3-6 Nov. 1994
Page(s): A6 -A7 vol.1

[Abstract]   [PDF Full-Text (108 KB)] **IEEE CNF**

4 **A wavelet localized Radon transform based detector for a signal with
unknown parameters**
Warrick, A.L.; Delaney, P.A.;
Signals, Systems and Computers, 1995. 1995 Conference Record of the
Twenty-Ninth Asilomar Conference on , Volume: 2 , 30 Oct.-2 Nov. 1995
Page(s): 860 -864 vol.2

[Abstract]   [PDF Full-Text (428 KB)] **IEEE CNF**

5 **Region-of-interest tomography using the wavelet transform and
angular harmonics**
Yagle, A.E.;
Image Processing, 1995. Proceedings., International Conference on , Volume: 2 ,
23-26 Oct. 1995
Page(s): 461 -463 vol.2

[Abstract]   [PDF Full-Text (236 KB)] **IEEE CNF**

6 **Detection of linear features using a localized Radon transform with a
wavelet filter**
Warrick, A.L.; Delaney, P.A.;
Acoustics, Speech, and Signal Processing, 1997. ICASSP-97., 1997 IEEE
International Conference on , Volume: 4 , 21-24 April 1997

Page(s): 2769 -2772 vol.4

[Abstract] [PDF Full-Text (280 KB)] **IEEE CNF**

---

7 A pattern detection and compression algorithm based on the joint wavelet and Radon transform
Magli, E.; Lo Presti, L.; Olmo, G.;
Digital Signal Processing Proceedings, 1997. DSP 97., 1997 13th International Conference on , Volume: 2 , 2-4 July 1997
Page(s): 559 -562 vol.2

[Abstract] [PDF Full-Text (460 KB)] **IEEE CNF**

---

8 Localized wavelet based computerized tomography
Rashid-Farrokhi, F.; Liu, K.J.R.; Berenstein, C.A.; Walnut, D.;
Image Processing, 1995. Proceedings., International Conference on , Volume: 2 , 23-26 Oct. 1995
Page(s): 445 -448 vol.2

[Abstract] [PDF Full-Text (568 KB)] **IEEE CNF**

---

9 Linear frequency modulated signal detection using wavelet packet, ambiguity function and Radon transform
Wang, M.M.; Chan, A.K.; Chui, C.K.;
Antennas and Propagation Society International Symposium, 1995. AP-S. Digest , Volume: 1 , 18-23 June 1995
Page(s): 308 -311 vol.1

[Abstract] [PDF Full-Text (160 KB)] **IEEE CNF**

---

10 Stochastic approximation by neural networks using the Radon and wavelet transforms
Meir, R.; Maiorov, V.;
Neural Networks for Signal Processing VIII, 1998. Proceedings of the 1998 IEEE Signal Processing Society Workshop , 31 Aug.-2 Sept. 1998
Page(s): 224 -233

[Abstract] [PDF Full-Text (400 KB)] **IEEE CNF**

---

11 Reconstruction by using a wavelet representation of the algebraic Radon transform
Mexas, J.G.F.; De Oliveira, A.; Esperanca, C.;
Computer Graphics and Image Processing, 2000. Proceedings XIII Brazilian Symposium on , 17-20 Oct. 2000
Page(s): 341

[Abstract] [PDF Full-Text (104 KB)] **IEEE CNF**

---

12 The application of wavelets correlator for ship wake detection in SAR images
Jin Min Kuo; Chen, K.-S.;
Geoscience and Remote Sensing, IEEE Transactions on , Volume: 41 Issue: 6 , June 2003
Page(s): 1506 -1511

[Abstract] [PDF Full-Text (867 KB)] **IEEE JNL**

---

13 Iterative inversion of the Radon transform
Sahiner, B.; Yagle, A.E.;
Engineering in Medicine and Biology Magazine, IEEE , Volume: 15 Issue: 5 , Sept.-Oct. 1996
Page(s): 112 -117

[Abstract] [PDF Full-Text (1088 KB)] **IEEE JNL**

14 **Wavelet-based multiresolution local tomography**
Rashid-Farrokhi, F.; Liu, K.J.R.; Berenstein, C.A.; Walnut, D.;
Image Processing, IEEE Transactions on , Volume: 6 Issue: 10 , Oct. 1997
Page(s): 1412 -1430

[Abstract] [PDF Full-Text (1260 KB)] **IEEE JNL**

15 **The curvelet transform for image denoising**
Jean-Luc Starck; Candes, E.J.; Donoho, D.L.;
Image Processing, IEEE Transactions on , Volume: 11 Issue: 6 , June 2002
Page(s): 670 -684

[Abstract] [PDF Full-Text (459 KB)] **IEEE JNL**

16 **Wavelet localization of the Radon transform in even dimensions**
DeStefano, J.; Olson, T.;
Time-Frequency and Time-Scale Analysis, 1992., Proceedings of the IEEE-SP
International Symposium , 4-6 Oct. 1992
Page(s): 137 -140

[Abstract] [PDF Full-Text (284 KB)] **IEEE CNF**

17 **Local vector tomography by use of wavelets**
Strahlen, K.;
Image Processing, 2000. Proceedings. 2000 International Conference on ,
Volume: 2 , 10-13 Sept. 2000
Page(s): 617 -620 vol.2

[Abstract] [PDF Full-Text (292 KB)] **IEEE CNF**

18 **Wavelet localization of the Radon transform**
Olson, T.; DeStefano, J.;
Signal Processing, IEEE Transactions on [see also Acoustics, Speech, and Signal
Processing, IEEE Transactions on] , Volume: 42 Issue: 8 , Aug. 1994
Page(s): 2055 -2067

[Abstract] [PDF Full-Text (1100 KB)] **IEEE JNL**

19 **Iterative inversion of the Radon transform using image-adaptive
wavelet constraints**
Sahiner, B.; Yagle, A.E.;
Image Processing, 1998. ICIP 98. Proceedings. 1998 International Conference on
, Volume: 2 , 4-7 Oct. 1998
Page(s): 709 -713 vol.2

[Abstract] [PDF Full-Text (432 KB)] **IEEE CNF**

20 **Determination of a segment endpoint by means of the Radon
transform**
Olmo, G.; Magli, E.;
Electronics, Circuits and Systems, 1999. Proceedings of ICECS '99. The 6th IEEE
International Conference on , Volume: 2 , 5-8 Sept. 1999
Page(s): 851 -854 vol.2

[Abstract] [PDF Full-Text (340 KB)] **IEEE CNF**

21 **Feature extraction of intra-pulse modulated signals using
time-frequency analysis**
Moraitakis, I.; Fargues, M.P.;
MILCOM 2000. 21st Century Military Communications Conference Proceedings ,
Volume: 2 , 22-25 Oct. 2000
Page(s): 737 -741 vol.2

[Abstract] [PDF Full-Text (440 KB)] **IEEE CNF**

---

22 Analysis of neural networks for face recognition systems with feature extraction to develop an eye localization based method
Rizk, M.R.M.; Taha, A.;
Electronics, Circuits and Systems, 2002. 9th International Conference on ,
Volume: 3 , 15-18 Sept. 2002
Page(s): 847 -850 vol.3

[Abstract] [PDF Full-Text (326 KB)] **IEEE CNF**

---

23 An algorithm for successive identification of reflections
Hansen, K.V.; Larsen, J.;
Image Processing, IEEE Transactions on , Volume: 3 Issue: 3 , May 1994
Page(s): 281 -291

[Abstract] [PDF Full-Text (892 KB)] **IEEE JNL**

---

24 On-board selection of relevant images: an application to linear feature recognition
Magli, E.; Olmo, G.; Lo Presti, L.;
Image Processing, IEEE Transactions on , Volume: 10 Issue: 4 , April 2001
Page(s): 543 -553

[Abstract] [PDF Full-Text (192 KB)] **IEEE JNL**

---

25 Regularization in tomographic reconstruction using thresholding estimators
Kalifa, J.; Laine, A.; Esser, P.D.;
Medical Imaging, IEEE Transactions on , Volume: 22 Issue: 3 , March 2003
Page(s): 351 -359

[Abstract] [PDF Full-Text (687 KB)] **IEEE JNL**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

Membership   Publications/Services   Standards   Conferences   Careers/Jobs

IEEE Xplore®
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Help   FAQ   Terms   IEEE Peer
Review

Quick Links

» Abstract Plus

Welcome to IEEE Xplore   SEARCH RESULTS   [PDF Full-Text (460 KB)]   PREVIOUS   NEXT   DOWNLOAD CITATION

O- Home
O- What Can
   I Access?
O- Log-out

Tables of Contents

O- Journals
   & Magazines
O- Conference
   Proceedings
O- Standards

Search

O- By Author
O- Basic
O- Advanced

Member Services

O- Join IEEE
O- Establish IEEE
   Web Account

O- Access the
   IEEE Member
   Digital Library

✉ Print Format

A pattern detection and compression algorithm based on the joint wavelet and Radon transform

Magli, E.   Lo Presti, L.   Olmo, G.
Dipt. di Elettronica, Politecnico di Torino;

Abstract:
The linear feature detection task can be efficiently accomplished by means of the joint Radon transform (RT) and continuous wavelet transform (CWT) analysis. With regard to the former, a fast algorithm for its computation is . described in detail, and the compression and robustness capabilities of the transform are discussed. It is found that the RT is suitable for transmission and fast detection purposes. A completely new, highly efficient CWT based algorithm, to be applied in addition to the classical thresholding methods in the Radon domain, is then discussed. The algorithm is capable to detect linear features even in the presence of large amounts of noise

Index Terms:
Radon transforms   data compression   feature extraction   image recognition   object recognition   transform coding   wavelet transforms   Radon domain   continuous wavelet transform   fast algorithm   joint wavelet/Radon transform   linear feature detection   object recognition   pattern compression   pattern detection   thresholding methods

Documents that cite this document
Select link to view other documents in the database that cite this one.

SEARCH RESULTS   [PDF Full-Text (460 KB)] PREVIOUS   NEXT   DOWNLOAD CITATION

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

◆IEEE

IEEE Xplore®
RELEASE 1.5

Welcome
United States Patent and Trademark Office

Quick Links   » Search Results

Welcome to IEEE Xplore

O- Home
O- What Can I Access?
O- Log-out

Tables of Contents

O- Journals & Magazines
O- Conference Proceedings
O- Standards

Search

O- By Author
O- Basic
O- Advanced

Member Services

O- Join IEEE
O- Establish IEEE Web Account
O- Access the IEEE Member Digital Library

Print Format

Your search matched **37** of **972916** documents.

A maximum of **37** results are displayed, **25** to a page, sorted by **Relevance** in descending order.
You may refine your search by editing the current search expression or entering a new one the text box.
Then click **Search Again**.

(wavelet and radon)   Search Again

Results:
Journal or Magazine = **JNL**   Conference = **CNF**   Standard = **STD**

26 **Ultrasonic tomography using arc focusing beam**
Takizawa, N.; Ohya, A.; Akiyama, I.;
Ultrasonics Symposium, 1998. Proceedings., 1998 IEEE, Volume: 2, 5-8 Oct. 1998
Page(s): 1659 -1662 vol.2

[Abstract] [PDF Full-Text (208 KB)] **IEEE CNF**

27 **On the use of wavelets in inverting the Radon transform**
Sahiner, B.; Yagle, A.E.;
Nuclear Science Symposium and Medical Imaging Conference, 1992., Conference Record of the 1992 IEEE, 25-31 Oct. 1992
Page(s): 1129 -1131 vol.2

[Abstract] [PDF Full-Text (260 KB)] **IEEE CNF**

28 **Matched wavelets-their construction, and application to object detection**
Chapa, J.O.; Raghuveer, M.R.;
Acoustics, Speech, and Signal Processing, 1996. ICASSP-96. Conference Proceedings., 1996 IEEE International Conference on, Volume: 5, 7-10 May 1996
Page(s): 2987 -2989 vol. 5

[Abstract] [PDF Full-Text (232 KB)] **IEEE CNF**

29 **A new automatic internal wave detection and characterization method for SAR images**
Rodenas, J.A.; Garello, R.;
OCEANS '98 Conference Proceedings, Volume: 2, 28 Sept.-1 Oct. 1998
Page(s): 613 -618 vol.2

[Abstract] [PDF Full-Text (756 KB)] **IEEE CNF**

30 **Directional noise removal from aerial imagery using wavelet X-ray transform**
Shijin Lu; Smith, W.F.; Holyer, R.J.; Chan, A.; Liu, S.J.;
Geoscience and Remote Sensing Symposium Proceedings, 1998. IGARSS '98. 1998 IEEE International, Volume: 4, 6-10 July 1998
Page(s): 2038 -2040 vol.4

[Abstract] [PDF Full-Text (404 KB)] **IEEE CNF**

31 **Ultrasonic pulsed echo tomography using narrow aperture phased array**
Akiyama, I.; Takizawa, N.; Ohya, A.;
Ultrasonics Symposium, 1999. Proceedings. 1999 IEEE, Volume: 2, 17-20 Oct.

1999
Page(s): 1613 -1616 vol.2

[Abstract] [PDF Full-Text (236 KB)] **IEEE CNF**

---

32 **Content-based image retrieval for not-well-framed images using multiresolutional eigen-features**
Joo, Y.B.; Jin, J.;
Multimedia and Expo, 2000. ICME 2000. 2000 IEEE International Conference on ,
Volume: 2 , 30 July-2 Aug. 2000
Page(s): 665 -668 vol.2

[Abstract] [PDF Full-Text (284 KB)] **IEEE CNF**

---

33 **The finite ridgelet transform for image representation**
Do, M.N.; Vetterli, M.;
Image Processing, IEEE Transactions on , Volume: 12 Issue: 1 , Jan. 2003
Page(s): 16 -28

[Abstract] [PDF Full-Text (941 KB)] **IEEE JNL**

---

34 **Iterative inversion of the Radon transform using image-adaptive wavelet constraints**
Sahiner, B.; Yagle, A.E.;
Engineering in Medicine and Biology Society, 1996. Bridging Disciplines for Biomedicine. Proceedings of the 18th Annual International Conference of the IEEE , Volume: 2 , 31 Oct.-3 Nov. 1996
Page(s): 722 -723 vol.2

[Abstract] [PDF Full-Text (192 KB)] **IEEE CNF**

---

35 **Wavelet-based multiscale stochastic models for efficient tomographic discrimination of fractal fields**
Bhatia, M.; Karl, W.C.; Willsky, A.S.;
Image Processing, 1994. Proceedings. ICIP-94., IEEE International Conference ,
Volume: 2 , 13-16 Nov. 1994
Page(s): 135 -139 vol.2

[Abstract] [PDF Full-Text (416 KB)] **IEEE CNF**

---

36 **Analytical algorithm for 3D cone-beam SPECT reconstruction with uniform attenuation correction**
Bronnikov, A.V.;
Nuclear Science Symposium, 1998. Conference Record. 1998 IEEE , Volume: 3 ,
8-14 Nov. 1998
Page(s): 1417 -1423 vol.3

[Abstract] [PDF Full-Text (516 KB)] **IEEE CNF**

---

37 **Orthonormal finite ridgelet transform for image compression**
Do, M.N.; Vetterli, M.;
Image Processing, 2000. Proceedings. 2000 International Conference on ,
Volume: 2 , 10-13 Sept. 2000
Page(s): 367 -370 vol.2

[Abstract] [PDF Full-Text (348 KB)] **IEEE CNF**

Home | Log-out | Journals | Conference Proceedings | Standards | Search by Author | Basic Search | Advanced Search
Join IEEE | Web Account | New this week | OPAC Linking Information | Your Feedback | Technical Support | Email Alerting
No Robots Please | Release Notes | IEEE Online Publications | Help | FAQ| Terms | Back to Top

Google

gindikin +"bolker" +"wavelet"   Google Search

Web   Images   Groups   Directory   News

Searched the web for gindikin +"bolker" +"wavelet".   Results 1 - 4 of 4. Search took 0.20 seconds.

Try Google Answers to get help from expert researchers.

The Finite Ridgelet Transform For Image Representation (...
... Ideal spatial adaptation via **wavelet** shrinkage (context ... Radon transform (context)
- **Bolker** - 1987 7 ... reconstruction (context) - Vvedenskaya, **Gindikin** - 1990 1 ...
citeseer.nj.nec.com/do01finite.html - 22k - Cached - Similar pages

[PDF]The Finite Ridgelet Transform for Image Representation
File Format: PDF/Adobe Acrobat - View as HTML
... Our construction uses the finite Radon transform (FRAT) (**Bolker**, 1987; Mat' u˘
s ... Taking the one-dimensional **wavelet** transform on the projections of the FRAT ...
lcavwww.epfl.ch/publications/02/ postscripts/DoVetterli2.pdf - Similar pages

[PDF]The Finite Ridgelet Transform for Image Representation
File Format: PDF/Adobe Acrobat - View as HTML
... It uses the finite Radon transform (**Bolker**, 1987; Mat' u˘s and Flusser, 1993) as ... show
that the new transform is more effective than the **wavelet** transform in ...
lcavwww.epfl.ch/~minhdo/publications/FRIT_trans.pdf - Similar pages

[PDF]Discrete Ridgelet Transforms for Image Representation
File Format: PDF/Adobe Acrobat - View as HTML
... representations are achieved via invertible and non redundant transforms Currently
the most popular choices for this purpose are the **wavelet** transform and the ...
icwww.epfl.ch/publications/documents/ IC_TECH_REPORT_200119.pdf - Similar pages

gindikin +"bolker" +"wavelet"   Google Search   Search within results

Dissatisfied with your search results? Help us improve.

Google Home - Advertise with Us - Business Solutions - Services & Tools - Jobs, Press, & Help

The Finite Ridgelet Transform For Image Representation
(2001) (Make Corrections)
Minh N. Do, Martin Vetterli

CiteSeer Home/Search Context Related

Rate this article: 1 2 3 4 5 (best)
Comment on this article

(Enter summary)

Abstract: The ridgelet transform (Cands and Donoho, 1999) was introduced as a new multiscale representation for functions on continuous spaces that are smooth away from discontinuities along lines. In this paper, we propose an orthonormal version of the ridgelet transform for discrete and finite-size images. It uses the finite Radon transform (Bolker, 1987; Matfi and Flusser, 1993) as a basic building block. The proposed transform is invertible, non-redundant and computed via fast algorithms.... (Update)

Active bibliography (related documents): More All
0.7: Orthonormal Finite Ridgelet Transform For Image Compression - Do, Vetterli (2000) (Correct)
0.5: Denoising Through Wavelet Shrinkage: An Empirical Study - Fodor, Kamath (Correct)
0.4: On The Compression Of Two-Dimensional Piecewise Smooth.. - Do, Dragotti, Shukla.. (Correct)

Similar documents based on text: More All
0.9: Cv - Do (Correct)
0.8: The Curvelet Transform for Image Denoising - Starck, Candès, Donoho (2000) (Correct)
0.7: Monoscale Ridgelets for the Representation of Images with Edges - Candès (1999) (Correct)

BibTeX entry: (Update)

```
@misc{ do-finite,
    author = "Minh N. Do and Martin Vetterli",
    title = "The Finite Ridgelet Transform For Image Representation",
    url = "citeseer.nj.nec.com/do01finite.html" }
```

Citations (may not include all citations):
1283 Ten Lectures on Wavelets (context) - Daubechies - 1992
511 Cambridge University Press (context) - Horn, Johnson et al. - 1985
320 A Wavelet Tour of Signal Processing (context) - Mallat - 1999
238 Wavelets and Subband Coding (context) - Vetterli, Kovafievid - 1995
181 Ideal spatial adaptation via wavelet shrinkage (context) - Donoho, Johnstone - 1994
164 Singularity detection and processing with wavelets - Mallat, Hwang - 1992
114 Discrete Cosine Transform: Algorithms (context) - Rao, Yip - 1990
99 Introduction to Finite Fields and Their Applications (context) - Lidl, Niederreiter - 1994
57 Image Reconstruction from Projections: The Fundamentals of C.. (context) - Herman - 1980
50 The Radon transform and some of its applications (context) - Deans - 1983
20 Wavelets and recursive filter banks (context) - Herley, Vetterli - 1993
19 Data compression and harmonic analysis - Donoho, Vetterli et al. - 1998
16 Ridgelets: a key to higher-dimensional intermittency (context) - Cands, Donoho - 1999
13 Classification of nonexpansive symmetric extension transorms.. (context) - Brislawn - 1996
10 Digital Picture Processing (context) - Rosenreid, Kak - 1982
7 The finite Radon transform (context) - Bolker - 1987
7 Digital reconstruction of multidimensional signals from proj.. (context) - Mersereau, Oppenheim - 1974
6 Radon and Projection Transform-Based Computer Vision (context) - Sanz, Hinkle et al. - 1988
5 The curvelet transform for image denoising - Starck, Cands et al. - 2000
4 Digital curvelet transform: strategy, implementation and exp.. - Donoho, Duncan - 2000
4 Discrete Radon transform (context) - Beylkin - 1987
3 Curvelets - a suprisingly effective nonadaptive representati.. (context) - Cands, Donoho - 1999
2 Tomography on the 3D-torus and crystals (context) - Salzberg, Figueroa - 1999
2 Ridgelets: theory and applications (context) - Cands - 1998
1 Discrete Radon transform and image reconstruction (context) - Vvedenskaya, **Gindikin** - 1990
1 Quantized rame expansions with erasures (context) - Goyal, Kovaevid et al. - 2001

1   The fast discrete Radon transform - I: Theory (context) - Kelley, Madisetti - 1993
1   Image representation via a finite Radon transform (context) - Matd, Flusset - 1993
1   A new efficient algorithm to compute the two-dimensional dis.. (context) - Gertnet - 1988
1   Fast slant stack: A notion of Radon transform for data in a .. (context) - Averbuch, Coifman et al. - 2001

Documents on the same site (http://lcavwww.epfl.ch/~minhdo/home.html): <u>More</u>
Integrated Browsing and Searching of Large Image Collections - Pecenovic, Do, Vetterli, Pu (2000)   <u>(Correct)</u>
Texture Similarity Measurement Using Kullback-Leibler Distance .. - Do, Vetterli (2000)   <u>(Correct)</u>
Rotation Invariant Texture Retrieval using Steerable.. - Do, Lozano, Vetterli (2000)   <u>(Correct)</u>

<u>Online articles have much greater impact</u> <u>More about CiteSeer</u> <u>Add search form to your site</u> <u>Submit documents</u> <u>Feedback</u>

The Finite Ridgelet Transform
for Image Representation

Minh N. Do, *Member, IEEE,* and Martin Vetterli, *Fellow, IEEE*

Abstract— The ridgelet transform (Candès and Donoho, 1999) was introduced as a sparse expansion for functions on continuous spaces that are smooth away from discontinuities along lines. In this paper, we propose an orthonormal version of the ridgelet transform for discrete and finite-size images. Our construction uses the finite Radon transform (FRAT) (Bolker, 1987; Matúš and Flusser, 1993) as a building block. To overcome the periodization effect of a finite transform, we introduce a novel ordering of the FRAT coefficients. Taking the one-dimensional wavelet transform on the projections of the FRAT in a special way results in the finite ridgelet transform (FRIT), which is invertible, non-redundant, and computed via fast algorithms. Furthermore, our construction leads to a family of directional and orthonormal bases for images. Numerical results show that the FRIT is more effective than the wavelet transform in approximating and denoising images with straight edges.

Keywords— wavelets, ridgelets, Radon transform, directional bases, discrete transforms, non-linear approximation, image representation, image denoising.

I. INTRODUCTION

Many image processing tasks take advantage of *sparse* representations of image data where most information is packed into a small number of samples. Typically, these representations are achieved via invertible and non-redundant transforms. Currently, the most popular choices for this purpose are the wavelet transform [1], [2], [3] and the discrete cosine transform [4].

The success of wavelets is mainly due to the good performance for piecewise smooth functions in one dimension. Unfortunately, such is not the case in two dimensions. In essence, wavelets are good at catching zero-dimensional or *point* singularities, but two-dimensional piecewise smooth signals resembling images have one-dimensional singularities. That is, smooth regions are separated by edges, and while edges are discontinuous across, they are typically smooth curves. Intuitively, wavelets in two dimensions are obtained by a tensor-product of one dimensional wavelets and they are thus good at isolating the discontinuity across an edge, but will not see the smoothness along the edge.

To overcome the weakness of wavelets in higher dimensions, Candès and Donoho [5], [6] recently pioneered a new

M. N. Do was with the Audiovisual Communications Laboratory, Department of Communication Systems, Swiss Federal Institute of Technology, Lausanne, Switzerland. He is now with the Department of Electrical and Computer Engineering and the Beckman Institute, University of Illinois, Urbana IL 61801 (email: minhdo@uiuc.edu).

M. Vetterli is with the Audiovisual Communications Laboratory, Department of Communication Systems, Swiss Federal Institute of Technology, Lausanne, Switzerland, and with the Department of Electrical Engineering and Computer Science, University of California, Berkeley CA 94720 (email: martin.vetterli@epfl.ch).

This work was supported in part by a Ph.D. Fellowship from the Department of Communication Systems, EPFL, and the Swiss National Science Foundation under Grant 21-52439.97.

system of representations named *ridgelets* which deal effectively with *line* singularities in 2-D. The idea is to map a line singularity into a point singularity using the Radon transform [7]. Then, the wavelet transform can be used to effectively handle the point singularity in the Radon domain. Their initial proposal was intended for functions defined in the *continuous* $\mathbb{R}^2$ space.

For practical applications, the development of *discrete* versions of the ridgelet transform that lead to algorithmic implementations is a challenging problem. Due to the radial nature of ridgelets, straightforward implementations based on discretization of continuous formulae would require interpolation in polar coordinates, and thus result in transforms that would be either redundant or can not be perfectly reconstructed.

In [8], [9], [10], the authors take the redundant approach in defining discrete Radon transforms that can lead to invertible discrete ridgelet transforms with some appealing properties. For example, a recent preprint [10] proposes a new notion of Radon transform for data in a rectangular coordinate such that the lines exhibit geometrical faithfulness. Their transform is invertible with a factor four over-sampled. However, the inverse transform is ill-conditioned in the presence of noise and requires an iterative approximation algorithm.

In this paper, we propose a discrete ridgelet transform that achieves both invertibility and non-redundancy. In fact, our construction leads to a large family of *orthonormal* and directional bases for digital images, including adaptive schemes. As a result, the inverse transform is numerically stable and uses the same algorithm as the forward transform. Because a basic building block in our construction is the finite Radon transform [11], which has a wrap-around (or aliased line) effect, our ridgelet transform is not geometrically faithful. The properties of the new transform are demonstrated and studied in several applications.

As an illustration, consider the image denoising problem where there exist other approaches that explore the geometrical regularity of edges, for example by chaining adjacent wavelet coefficients and then thresholding them over those contours [12]. However, the discrete ridgelet transform approach, with its "built-in" linear geometrical structure, provide a more direct way – by simply thresholding significant ridgelet coefficients – in denoising images with straight edges.

The outline of this paper is as follows. In the next section we review the concept and motivation of ridgelets in the continuous domain. In Section III, we introduce the finite Radon transform with a novel ordering of coefficients as a key step in our discrete ridgelet construction. The

finite Radon transform is then studied within the theory of frames. The finite ridgelet transform is defined in Section IV, where the main result is a general family of orthonormal transforms for digital images. In Sections V, we propose several variations on the initial design of the finite ridgelet transform. Numerical experiments are presented in Section VI, where the new transform is compared with the traditional ones, especially the wavelet transform. We conclude in Section VII with some discussions and an outlook.

II. Continuous Ridgelet Transform

We start by briefly reviewing the ridgelet transform and showing its connections with other transforms in the continuous domain. Given an integrable bivariate function $f(\boldsymbol{x})$, its *continuous ridgelet transform* (CRT) in $\mathbb{R}^2$ is defined by [5], [6]

$$CRT_f(a, b, \theta) = \int_{\mathbb{R}^2} \psi_{a,b,\theta}(\boldsymbol{x}) f(\boldsymbol{x}) d\boldsymbol{x}, \qquad (1)$$

where the ridgelets $\psi_{a,b,\theta}(\boldsymbol{x})$ in 2-D are defined from a wavelet-type function in 1-D $\psi(x)$ as

$$\psi_{a,b,\theta}(\boldsymbol{x}) = a^{-1/2}\psi((x_1 \cos\theta + x_2 \sin\theta - b)/a). \qquad (2)$$

Figure 1 shows an example ridgelet function, which is oriented at an angle θ and is constant along the lines $x_1 \cos\theta + x_2 \sin\theta = const.$
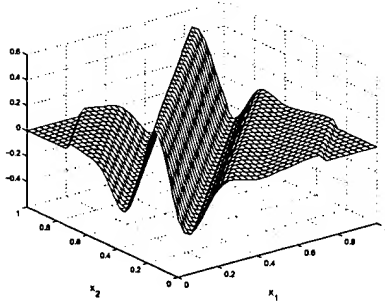

Fig. 1. An example ridgelet function $\psi_{a,b,\theta}(x_1, x_2)$.

For comparison, the (separable) continuous wavelet transform (CWT) in $\mathbb{R}^2$ of $f(\boldsymbol{x})$ can be written as

$$CWT_f(a_1, a_2, b_1, b_2) = \int_{\mathbb{R}^2} \psi_{a_1,a_2,b_1,b_2}(\boldsymbol{x}) f(\boldsymbol{x}) d\boldsymbol{x}, \qquad (3)$$

where the wavelets in 2-D are tensor products

$$\psi_{a_1,a_2,b_1,b_2}(\boldsymbol{x}) = \psi_{a_1,b_1}(x_1)\psi_{a_2,b_2}(x_2), \qquad (4)$$

of 1-D wavelets, $\psi_{a,b}(t) = a^{-1/2}\psi((t - b)/a).$[1]

As can be seen, the CRT is similar to the 2-D CWT except that the *point* parameters (b_1, b_2) are replaced by the

[1]In practice, however one typically enforces the same dilation scale on both directions thus leading to three wavelets corresponding to horizontal, vertical and diagonal directions.

line parameters (b, θ). In other words, these 2-D multiscale transforms are related by:

Wavelets:　$\rightarrow$　$\psi_{scale, \, point-position}$,
Ridgelets:　$\rightarrow$　$\psi_{scale, \, line-position}.$

As a consequence, wavelets are very effective in representing objects with isolated point singularities, while ridgelets are very effective in representing objects with singularities along lines. In fact, one can think of ridgelets as a way of concatenating 1-D wavelets along lines. Hence the motivation for using ridgelets in image processing tasks is appealing since singularities are often joined together along edges or contours in images.

In 2-D, points and lines are related via the Radon transform, thus the wavelet and ridgelet transforms are linked via the Radon transform. More precisely, denote the Radon transform as

$$R_f(\theta, t) = \int_{\mathbb{R}^2} f(\boldsymbol{x})\delta(x_1 \cos\theta + x_2 \sin\theta - t) d\boldsymbol{x}, \qquad (5)$$

then the ridgelet transform is the application of a 1-D wavelet transform to the slices (also referred to as projections) of the Radon transform,

$$CRT_f(a, b, \theta) = \int_{\mathbb{R}} \psi_{a,b}(t) R_f(\theta, t) dt. \qquad (6)$$

It is instructive to note that if in (6) instead of taking a 1-D wavelet transform, the application of a 1-D Fourier transform along t would result in the 2-D Fourier transform. More specifically, let $F_f(\boldsymbol{\omega})$ be the 2-D Fourier transform of $f(\boldsymbol{x})$, then we have

$$F_f(\xi \cos\theta, \xi \sin\theta) = \int_{\mathbb{R}} e^{-j\xi t} R_f(\theta, t) dt. \qquad (7)$$

This is the famous *projection-slice* theorem and is commonly used in image reconstruction from projection methods [13], [14]. The relations between the various transforms are depicted in Figure 2.
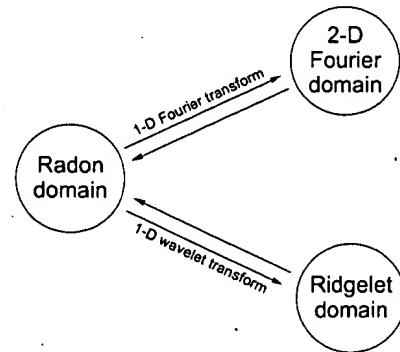

Fig. 2. Relations between transforms. The ridgelet transform is the application of 1-D wavelet transform to the slices of the Radon transform, while the 2-D Fourier transform is the application of 1-D Fourier transform to those Radon slices.

III. FINITE RADON TRANSFORM

A. Forward and Inverse Transforms

As suggested in the previous section, a discrete ridgelet transform can be constructed using a discrete Radon transform. Numerous discretizations of the Radon transforms have been devised to approximate the continuous formulae [15], [13], [14], [16], [17], [18]. However, most of them were not designed to be invertible transforms for digital images. Alternatively, the *finite* Radon transform theory (which means transform for *finite* length signals) [11], [19], [20], [21] originated from combinatorics, provides an interesting solution. Also, in [22], a closely related transform is derived from the periodization of the continuous Radon transform.

The *finite Radon transform* (FRAT) is defined as summations of image pixels over a certain set of "lines". Those lines are defined in a finite geometry in a similar way as the lines for the continuous Radon transform in the Euclidean geometry. Denote $Z_p = \{0, 1, \ldots, p-1\}$, where p is a prime number. Note that Z_p is a finite field with modulo p operations [23]. For later convenience, we denote $Z_p^* = \{0, 1, \ldots, p\}$.

The FRAT of a real function f on the finite grid Z_p^2 is defined as

$$r_k[l] = FRAT_f(k, l) = \frac{1}{\sqrt{p}} \sum_{(i,j) \in L_{k,l}} f[i, j]. \qquad (8)$$

Here $L_{k,l}$ denotes the set of points that make up a line on the lattice Z_p^2, or more precisely

$$L_{k,l} = \{(i, j) : j = ki + l \pmod{p}, i \in Z_p\}, \quad 0 \le k < p,$$
$$L_{p,l} = \{(l, j) : j \in Z_p\}. \qquad (9)$$

Figure 3 shows an example of the finite lines $L_{k,l}$ where points in the grid Z_p^2 are represented by image pixels. Note that due to the modulo operations in the definition of lines for the FRAT, these lines exhibit a "wrap around" effect. In other words, the FRAT treat the input image as one period of a periodic image. Later, we will present several ways to limit this artifact.

We observe that in the FRAT domain, the energy is best compacted if the mean is subtracted from the image $f[i, j]$ prior to taking the transform given in (8), which is assumed in the sequel. We also introduce the factor $p^{-1/2}$ in order to normalize the l_2-norm between the input and output of the FRAT.

Just as in the Euclidean geometry, a line $L_{k,l}$ on the affine plane Z_p^2 is uniquely represented by its slope or direction $k \in Z_p^*$ ($k = p$ corresponds to infinite slope or vertical lines) and its intercept $l \in Z_p$. One can verify that there are $p^2 + p$ lines defined in this way and every line contains p points. Moreover, any two distinct points on Z_p^2 belong to just one line. Also, two lines of different slopes intersect at exactly one point. For any given slope, there are p parallel lines that provide a complete cover of the
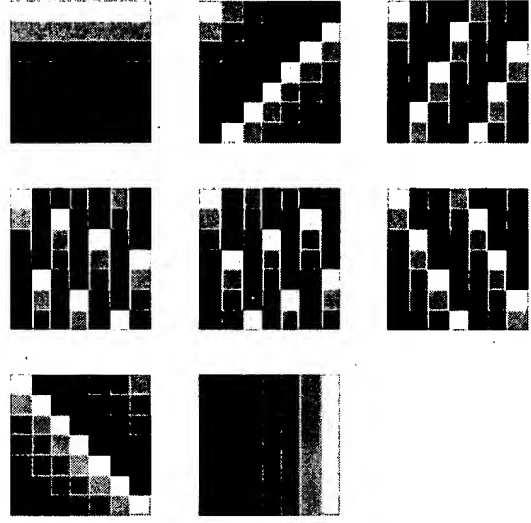

Fig. 3. Lines for the 7×7 FRAT. Parallel lines are grouped in each of the eight possible directions. Images in order from top to bottom, left to right are corresponding to the values of k from 0 to 7. In each image, points (or pixels) in different lines are assigned with different gray-scales.

plane Z_p^2. This means that for an input image $f[i, j]$ with zero-mean, we have

$$\sum_{l=0}^{p-1} r_k[l] = \frac{1}{\sqrt{p}} \sum_{(i,j) \in Z_p^2} f[i, j] = 0 \quad \forall k \in Z_p^*. \qquad (10)$$

Thus, (10) explicitly reveals the redundancy of the FRAT: in each direction, there are only $p-1$ independent FRAT coefficients. Those coefficients at $p+1$ directions together with the mean value make up totally of $(p+1)(p-1)+1 = p^2$ independent coefficients (or degrees of freedom) in the finite Radon domain, as expected.

By analogy with the continuous case, the *finite back-projection* (FBP) operator is defined as the sum of Radon coefficients of all the lines that go through a given point, that is

$$FBP_r(i, j) = \frac{1}{\sqrt{p}} \sum_{(k,l) \in P_{i,j}} r_k[l], \quad (i, j) \in Z_p^2, \qquad (11)$$

where $P_{i,j}$ denotes the set of indices of all the lines that go through a point $(i, j) \in Z_p^2$. More specifically, using (9) we can write

$$P_{i,j} = \{(k, l) : l = j - ki \pmod{p}, k \in Z_p\} \cup \{(p, i)\}. \qquad (12)$$

From the property of the finite geometry Z_p^2 that every two points lie on exactly one line, it follows that every point in Z_p^2 lies on exactly one line from the set $P_{i,j}$, except for the point (i, j) which lies on all $p+1$ lines. Thus, by

substituting (8) into (11) we obtain

$$
\begin{aligned}
FBP_r(i,j) &= \frac{1}{p} \sum_{(k,l) \in P_{i,j}} \sum_{(i',j') \in L_{k,l}} f[i',j'] \\
&= \frac{1}{p} \left(\sum_{(i',j') \in Z_p^2} f[i',j'] + p.f[i,j] \right) \\
&= f[i,j].
\end{aligned}
\tag{13}
$$

So the back-projection operator defined in (11) indeed computes the inverse FRAT for zero-mean images. Therefore we have an efficient and exact reconstruction algorithm for the FRAT. Furthermore, since the FBP operator is the adjoint of the FRAT operator, the algorithm for the inverse of FRAT has the same structure and is symmetric with the algorithm for the forward transform.

It is easy to see that the FRAT requires *exactly* p^3 additions and p^2 multiplications. Moreover, for memory access efficiency, [20] describes an algorithm for the FRAT in which for each projection k we need to pass through every pixel of the original image only once using p histogrammers, one for each summation in (8) of that projection. For images of moderate sizes, we observed that the actual computational time of the FRAT is compatible with other $O(p^2 \log(p^2))$ transforms, such as the 2-D FFT, where the leading constant can be large. For example, on a Sun Ultra 5 computer, both the forward and inverse FRAT's take less than a second to compute on an image of size 257×257.

B. Optimal Ordering of the Finite Radon Transform Coefficients

The FRAT described in Section III-A uses (9) as a convenient way of specifying finite lines on the Z_p^2 grid via two parameters: the slope k and the intercept l. However it is neither a unique nor the best way for our purpose. Let us consider a more general definition of lines on the finite Z_p^2 plane as

$$
L'_{a,b,t} = \left\{ (i,j) \in Z_p^2 : ai + bj - t = 0 \pmod{p} \right\}, \tag{14}
$$

where $a, b, t \in Z_p$ and $(a,b) \neq (0,0)$.

This is by analogy with the line equation: $x_1 \cos \theta + x_2 \sin \theta - t = 0$ in $\mathbb{R}^2$. Therefore, for a finite line defined as in (14), (a,b) has the role of the normal vector, while t is the translation parameter. In this section, all equations involving line parameters are carried out in the finite field Z_p, which is assumed in the sequel without the indication of mod p.

It is easy to verify that for a fixed normal vector (a,b), $\left\{ L'_{a,b,t} : t \in Z_p \right\}$ is a set of p parallel lines in the Z_p^2 plane. This set is equal to the set of p lines $\{L_{k,l} : l \in Z_p\}$ defined in (9) with the same slope k, where $k = -b^{-1}a$ for $b \neq 0$ and $k = p$ for $b = 0$. Moreover, the set of lines with the normal vector (a,b) is equal to the set of lines with the normal vector (na, nb), for each $n = 1, 2, \ldots, p-1$.

With the general line specification in (14), we now define the new FRAT to be

$$
r_{a,b}[t] = FRAT_f(a,b,t) = \frac{1}{\sqrt{p}} \sum_{(i,j) \in L'_{a,b,t}} f[i,j]. \tag{15}
$$

From the discussion above we see that a new FRAT projection sequence: $(r_{a,b}[0], r_{a,b}[1], \ldots, r_{a,b}[p-1])$, is simply a reordering of a projection sequence $(r_k[0], r_k[1], \ldots, r_k[p-1])$ from (8). This ordering is important for us since we later apply a 1-D wavelet transform on each FRAT projection. Clearly, the chosen normal vectors (a,b) control the order for the coefficients in each FRAT's projection, as well as the represented directions of those projections.

The usual FRAT described in Section III-A uses the set of $(p+1)$ normal vectors u_k, where

$$
\begin{aligned}
u_k &= (-k, 1) \quad \text{for } k = 0, 1, \ldots, p-1, \text{ and} \\
u_p &= (1, 0).
\end{aligned}
\tag{16}
$$

In order to provide a complete representation, we need the FRAT to be defined as in (15) with a set of $p+1$ normal vectors $\left\{ (a_k, b_k) : k \in Z_p^* \right\}$ such that they cover all $p+1$ distinct FRAT projections represented by $\left\{ u_k : k \in Z_p^* \right\}$. We have $p-1$ choices for each of those normal vectors as

$$
(a_k, b_k) = n u_k, \quad 1 \leq n \leq p-1.
$$

So what is the good choice for the $p+1$ normal vectors of the FRAT? To answer this we first prove the following projection slice theorem for the general FRAT. A special case of this theorem is already shown in [20].

Defining $W_p = e^{-2\sqrt{-1}\pi/p}$, the *discrete Fourier transform* (DFT) of a function f on Z_p^2 can be written as

$$
F[u,v] = \frac{1}{p} \sum_{(i,j) \in Z_p^2} f[i,j] W_p^{ui+vj}, \tag{17}
$$

and for FRAT projections on Z_p as

$$
R_{a,b}[w] = \frac{1}{\sqrt{p}} \sum_{t \in Z_p} r_{a,b}[t] W_p^{wt}. \tag{18}
$$

Theorem 1 (Discrete projection-slice theorem) The 1-D DFT $R_{a,b}[w]$ of a FRAT projection $r_{a,b}[t]$ is identical to the 2-D DFT $F[u,v]$ of $f[i,j]$ evaluated along a discrete slice through the origin at direction (a,b):

$$
R_{a,b}[w] = F[aw, bw]. \tag{19}
$$

Proof: Substituting (15) into (18) and using the fact that the set of p parallel lines $\left\{ L'_{a,b,t} : t \in Z_p \right\}$ provides a complete cover of the plane Z_p^2, we obtain

$$
\begin{aligned}
R_{a,b}[w] &= \frac{1}{p} \sum_{t \in Z_p} \sum_{(i,j) \in L'_{a,b,t}} f[i,j] W_p^{wt} \\
&= \frac{1}{p} \sum_{(i,j) \in Z_p^2} f[i,j] W_p^{w(ai+bj)} \\
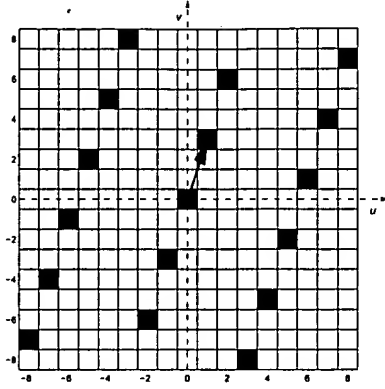&= F[aw, bw].
\end{aligned}
$$

Fig. 4. Example of a discrete Fourier slice (indicated by the black squares) with the best normal vector for that FRAT projection. In this example, $p = 17$ and the slope $k = 11$. The normal vector can be chosen as a vector from the origin to any other points on the Fourier slide. The best normal vector is $(1, 3)$ (the solid arrow).
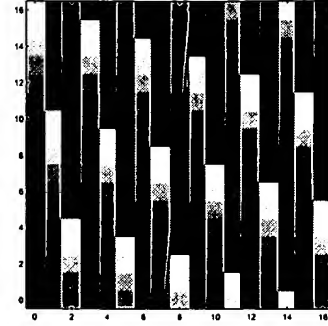

(a)

(b)

Fig. 5. Lines for the FRAT projection as shown in Figure 4 using: (a) usual ordering, (b) optimal ordering. They both represent the same set of lines but with different orderings. The orderings are signified by the increasing of gray-scales. The arrows indicate the represented directions in each case.

From (19), we can see the role of the FRAT normal vectors (a, b) in the DFT domain: it controls the order of the coefficients in the corresponding Fourier slices. In particular, $F[a, b]$ equals to the first harmonic component of the FRAT projection sequence with the normal vector (a, b). For the type of images that we are interested in, e.g. of natural scenes, most of the energy is concentrated in the low frequencies. Therefore in these cases, in order to ensure that each FRAT projection is smooth or low frequency dominated so that it can be represented well by the wavelet transform, the represented normal vector (a, b) should be chosen to be as "close" to the origin of the Fourier plane as possible. .

Figure 4 illustrates this by showing an example of a discrete Fourier slice. The normal vector for the corresponding FRAT projection can be chosen as a vector from the origin to *any* other point on the Fourier slice. However, the best normal vector is selected as the closest point to the origin. The choice of the normal vector (a, b) as the closest point to the origin causes the represented direction of the FRAT projection to have the least "wrap around" due to the periodization of the transform. The effect of the new ordering of FRAT coefficient in the image domain is illustrated in Figure 5 for the same example projection. As can be seen, the "wrap around" effect is significantly reduced with the optimal ordering compared to the usual one.
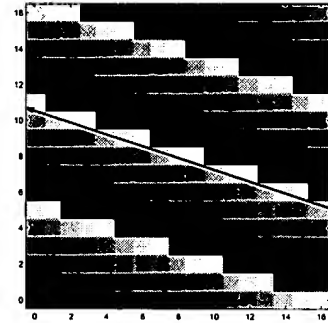
Formally, we define the set of $p+1$ optimal normal vectors $\left\{(a_k^\star, b_k^\star) : k \in Z_p^*\right\}$ as follows

$$(a_k^\star, b_k^\star) = \arg \min_{\substack{(a_k, b_k) \in \{n u_k : 1 \leq n \leq p-1\} \\ \text{s.t. } C_p(b_k) \geq 0}} \|(C_p(a_k), C_p(b_k))\|.$$

(20)

Here $C_p(x)$ denotes the centralized function of period p: $C_p(x) = x - p.\text{round}(x/p)$. Hence, $\|(C_p(a_k), C_p(b_k))\|$ represents the distance from the origin to the point (a_k, b_k)

on the periodic Fourier plane as shown in Figure 4. The constraint $C_p(b_k) \geq 0$ is imposed in order to remove the ambiguity in deciding between (a, b) and $(-a, -b)$ as the normal vector for a projection. As a result, the optimal normal vectors are restricted to have angles in $[0, \pi)$. We use norm-2 for solving (20). Minimization is simply done for each $k \in Z_p^*$ by computing $p - 1$ distances in (20) and select the smallest one. Figure 6 shows an example of the optimal set of normal vectors. In comparison with the usual set of normal vectors $\left\{u_k : k \in Z_p^*\right\}$ as given in (16), the new set $\left\{(a_k^\star, b_k^\star) : k \in Z_p^*\right\}$ provides a much more uniform angular coverage.

After obtaining the set of normal vectors $\left\{(a_k^\star, b_k^\star)\right\}$, we can compute the FRAT and its inverse with the same fast algorithms using histogrammers described in Section III-A. For a given p, solving (20) requires $O(p^2)$ operations and therefore it is negligible compared to the transforms themselves. Furthermore, this can be pre-computed, thus only presents as a "one-time" cost.

For the sake of simplicity, we write $r_k[t]$ for $r_{a_k^\star, b_k^\star}[t]$ in the sequel. In other words, from now we regard k as an index in the set of optimal FRAT normal vectors rather than a slope. Likewise, the line $L'_{a_k^\star, b_k^\star, t}$ is simply rewritten as $L_{k,t}$, for $0 \leq k \leq p$, $0 \leq t < p$.
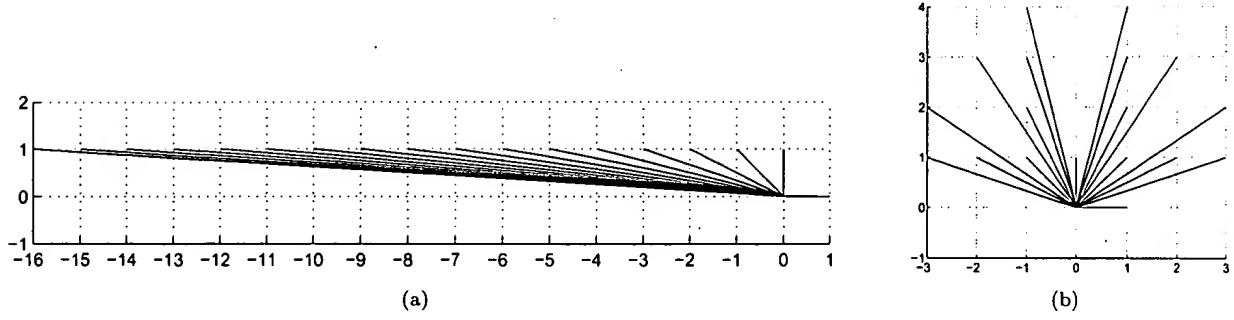
Fig. 6.   The set of normal vectors, which indicate the represented directions, for the FRAT of size $p = 17$ using: (a) usual ordering; (b) optimal ordering.

C. Frame Analysis of the FRAT

Since the FRAT is a redundant transform, it can be studied as a *frame operator*. In this section we will study the FRAT in more detail and reveal some of its properties in this frame setting. A detailed introduction to frames can be found in [24], [3].

Suppose that $\mathcal{F}$ is a linear operator from $\mathbb{R}^N$ to $\mathbb{R}^M$, defined by

$$(\mathcal{F}x)_n = \langle x, \varphi_n \rangle, \qquad \text{for } n = 1, \dots, M. \qquad (21)$$

The set $\{\varphi_n\}_{n=1}^M \subset \mathbb{R}^N$ is called a frame of $\mathbb{R}^N$ if there exist two constants $A > 0$ and $B < \infty$ such that

$$A\|x\|^2 \le \sum_{n=1}^M |\langle x, \varphi_n \rangle|^2 \le B\|x\|^2, \qquad \forall x \in \mathbb{R}^N. \qquad (22)$$

where A and B are called the frame bounds. When $A = B$ the frame is said to be tight. If the frame condition is satisfied then $\mathcal{F}$ is called a frame operator. It can be shown that any finite set of vectors that spans $\mathbb{R}^N$ is a frame. The frame bound ratio B/A indicates the numerical stability in reconstructing x from $(\mathcal{F}x)_n$; the tighter the frame, the more stable the reconstruction against coefficient noise.

The frame operator can be regarded as a left matrix multiplication with F, where F is an $M \times N$ matrix in which its nth row equals to φ_n. The frame condition (22) can be rewritten as

$$x^T A x \le x^T F^T F x \le x^T B x, \qquad \forall x \in \mathbb{R}^N. \qquad (23)$$

Since $F^T F$ is symmetric, it is diagonalizable in an orthonormal basis [25], thus (23) implies that the eigenvalues of $F^T F$ are between A and B. Therefore, the tightest possible frame bounds A and B are the minimum and maximum eigenvalues of $F^T F$, respectively. In particular, a tight frame is equivalent to $F^T F = A \cdot I$, which means the transpose of F equals to its left inverse within a scale factor A.

Now let us return to the FRAT. Since it is invertible it can be regarded as a frame operator in $l_2(Z_p^2)$ with the frame $\{\varphi_{k,l} : k \in Z_p^*, l \in Z_p\}$ defined as

$$\varphi_{k,l} = p^{-1/2} \delta_{L_{k,l}} \qquad (24)$$

where δ_S denotes the characteristic function for the set S, which means $\delta_S[i,j]$ equals to 1 if $(i,j) \in S$ and 0 otherwise. Note that this frame is normalized since $\|\varphi_{(k,l)}\| = 1$. By writing images as column vectors, the FRAT can be regarded as a left matrix multiplication with $F = p^{-1/2}R$, where $\{R\}_{(k,l),\,(i,j)}$ is the $(p^2 + p) \times p^2$ incidence matrix of the affine geometry Z_p^2: $R_{(k,l),\,(i,j)}$ equals to 1 if $(i,j) \in L_{k,l}$ and 0 otherwise.

Proposition 1: The tightest bounds for the FRAT frame $\{\varphi_{k,l} : k \in Z_p^*, l \in Z_p\}$ in $l_2(Z_p^2)$ are $A = 1$ and $B = p+1$.
Proof: From (23), these tightest bounds can be computed from the eigenvalues of $C = F^T F = p^{-1}R^T R$. Since R is the incidence matrix for lines in Z_p^2, $(R^T R)_{(i,j),\,(i',j')}$ equals the number of lines that go through both (i,j) and (i',j'). Using the properties of the finite geometry Z_p^2 that every two points lie in exactly one line and that there are exactly $p + 1$ lines that go through each point, it follows that the entries of C equal to $(p+1)p^{-1}$ along its diagonal and p^{-1} elsewhere.

The key observation is that C is a circulant matrix, hence its eigenvalues can be computed as the p^2-points discrete Fourier transform (DFT) on its first column $c = ((p + 1)p^{-1}, p^{-1}, \dots, p^{-1})$ [1] (§2.4.8). Writing c as

$$c = (1, 0, \dots, 0) + p^{-1} \cdot (1, 1, \dots, 1),$$

we obtain,

$$DFT\{c\} = (1, 1, \dots, 1) + p \cdot (1, 0, 0, \dots, 0) = (p+1, 1, 1, \dots, 1)$$

where the DFT is computed for the Dirac and constant signals.

Therefore the eigenvalues of C are $p+1$ and 1, the latter with multiplicity of $p^2 - 1$. As a result, the tightest (normalized) frame bounds for FRAT as $A = 1$ and $B = p+1$. ∎

For reconstruction, the FBP defined in (11) can be represented by a left multiplication with matrix $p^{-1/2}B$, where $B_{(i,j),\,(k,l)}$ equals to 1 if $(k,l) \in P_{i,j}$ and 0 otherwise. From the definition of $P_{i,j}$, we have

$$R_{(k,l),\,(i,j)} = B_{(i,j),\,(k,l)}, \qquad \forall i,j,k,l.$$

So the transform matrices for the operators FRAT and FBP are transposed of each other. Let $\bar{Z}_p^2$ denotes the

subspace of zero-mean images defined on Z_p^2. Since the FBP is an inverse of the FRAT for zero-mean images, we have the following result.

Proposition 2: On the subspace of zero-mean images $\bar{Z}_p^2$, the FRAT is a *normalized tight frame* with $A = B = 1$, which means

$$f = \sum_{k=0}^{p} \sum_{l=0}^{p-1} \langle f, \varphi_{k,l} \rangle \varphi_{k,l}, \quad \forall f \in \bar{Z}_p^2. \tag{25}$$

Remark 1: It is instructive to note that constant images on Z_p^2 are eigenvectors of $C = F^T F$ with the eigenvalue $p + 1$. Taking constant images out leaves a system with all unity eigenvalues, or a tight frame on the remaining subspace. Thus, we have another interpretation of FRAT being a normalized tight frame for zero-mean images.

By subtracting the mean from the image before applying the FRAT, we change the frame bound ratio from $p+1$ to 1 and obtain a tight frame. Consequently, this makes the reconstruction more robust against noise on the FRAT coefficients due to thresholding and/or quantization. This follows from the result in [26] that with the additive white noise model for the coefficients, the tight frame is optimal among normalized frames in minimizing mean-squared error.

IV. ORTHONORMAL FINITE RIDGELET TRANSFORM

With an invertible FRAT and applying (6), we can obtain an invertible discrete ridgelet transform by taking the discrete wavelet transform (DWT) on each FRAT projection sequence, $(r_k[0], r_k[1], \ldots, r_k[p-1])$, where the direction k is fixed. We call the overall result the *finite ridgelet transform* (FRIT). Figure 7 depicts these steps.
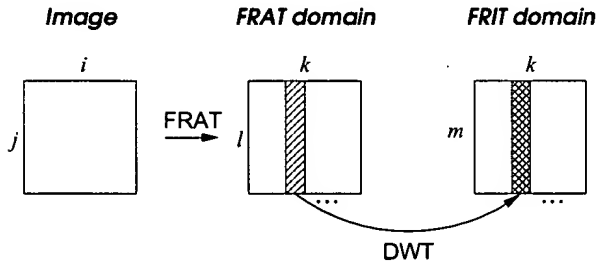

Fig. 7. Diagram for the FRIT. After taking the FRAT, a DWT is applied on each of the FRAT slices or projections where k is fixed.

Typically p is not dyadic, therefore a special border handling is required. Appendix A details one possible way of computing the DWT for prime length signals. Due to the periodicity property of the FRAT coefficients for each direction, periodic wavelet transforms are chosen and assumed in this section.

Recall that the FRAT is redundant and not orthogonal. Next we will show that by taking the 1-D DWT on the projections of the FRAT in a special way, we can remove this redundancy and obtain an orthonormal transform.

Assume that the DWT is implemented by an orthogonal tree-structured filter bank with J levels, where G_0 and G_1

are low and high pass synthesis filters, respectively. Then the family of functions:

$$\left\{ g_0^{(J)}[\cdot - 2^J m], \; g_1^{(j)}[\cdot - 2^j m] \; : \; j = 1, \ldots, J; \; m \in \mathbb{Z} \right\}$$

is the orthogonal basis of the discrete-time wavelet series [1]. Here $G^{(j)}$ denotes the equivalent synthesis filters at level j, or more specifically

$$G_0^{(J)}(z) = \prod_{k=0}^{J-1} G_0(z^{2^k}),$$

$$G_1^{(j)}(z) = G_1(z^{2^{j-1}}) \prod_{k=0}^{j-2} G_0(z^{2^k}), \quad j = 1, \ldots, J.$$

The basis functions from $G_0^{(J)}$ are called the scaling functions, while all the others functions in the wavelet basis are called wavelet functions. Typically, the filter G_1 is designed to satisfy the high pass condition, $G_1(z)|_{z=1} = 0$ so that the corresponding wavelet has at least one vanishing moment. Therefore, $G_1^{(j)}(z)|_{z=1} = 0$, $\forall j = 1, \ldots, J$, which means all wavelet basis functions have zero mean.

For a more general setting, let us assume that we have a collection of $(p + 1)$ 1-D orthonormal transforms on $\mathbb{R}^p$ (which can be the same), one for each projection k of FRAT, that have bases as

$$\left\{ w_m^{(k)} \; : \; m \in Z_p \right\}, \quad k = 0, 1, \ldots, p.$$

The only condition that we require for each of these bases can be expressed equivalently by the following lemma.

Lemma 1 (Condition Z) Suppose that $\{w_m : m \in Z_p\}$ is an orthogonal basis for the finite-dimensional space $\mathbb{R}^p$, then the following are equivalent:
1. This basis contains a constant function, say w_0, i.e. $w_0[l] = const$, $\forall l \in Z_p$.
2. All other basis functions, w_m, $m = 1, \ldots, p - 1$, have zero mean.

Proof: Denote $\mathbf{1} = (1, 1, \ldots, 1) \in \mathbb{R}^p$. If $w_0 = c\mathbf{1}$, $c \neq 0$ then from the orthogonality assumption that $\langle w_0, w_m \rangle = 0$, we obtain $\sum_l w_m[l] = 0$, $\forall m = 1, \ldots, p - 1$.

Conversely, assume that each basis function w_m, $1 \leq m \leq p - 1$, has zero mean. Denote S the subspace that is spanned by these functions and $S^\perp$ is its orthogonal complement subspace in $\mathbb{R}^p$. It is clear that $S^\perp$ has dimension 1 with w_0 as its basis. Consider the subspace $S_0 = \{c\mathbf{1} : c \in \mathbb{R}\}$. We have $\langle c\mathbf{1}, w_m \rangle = c \sum_l w_m[l] = 0$, $\forall m = 1, \ldots, p - 1$, thus $S_0 \subset S^\perp$. On the other hand, $\dim(S_0) = \dim(S^\perp) = 1$, therefore $S^\perp = S_0$. This means w_0 is a constant function. ∎

As shown before, the *Condition Z* is satisfied for all wavelet bases, or in fact any general tree-structured filter banks where the all-lowpass branch is carried to the maximum number of stages (i.e. when only one scaling coefficient is left).

By definition, the FRIT can be written as

$$FRIT_f[k,m] = \langle FRAT_f[k,\cdot], w_m^{(k)}[\cdot]\rangle$$
$$= \sum_{l \in Z_p} w_m^{(k)}[l]\langle f, \varphi_{k,l}\rangle$$
$$= \langle f, \sum_{l \in Z_p} w_m^{(k)}[l]\ \varphi_{k,l}\rangle. \quad (26)$$

Here $\{\varphi_{k,l}\}$ is the FRAT frame which is defined in (24). Hence we can write the basis functions for the FRIT as follows:

$$\rho_{k,m} = \sum_{l \in Z_p} w_m^{(k)}[l]\ \varphi_{k,l}. \quad (27)$$

We can next prove the result on the orthogonality of a modified FRIT.

Theorem 2: Given $p + 1$ orthonormal bases in $l^2(Z_p)$ (which can be the same): $\left\{w_m^{(k)} : m \in Z_p\right\}$, $0 \le k \le p$, that satisfy the *Condition Z* then

$$\{\rho_{k,m}\ :\ k = 0, 1, \ldots, p;\ m = 1, 2, \ldots, p-1\} \cup \{\rho_0\}$$

is an orthonormal basis in $l^2(Z_p^2)$, where $\rho_{k,m}$ are defined in (27) and ρ_0 is the constant function, $\rho_0[i,j] = 1/p$, $\forall (i,j) \in Z_p^2$.

Proof: Let us consider the inner products between any two FRIT basis functions

$$\langle \rho_{k,m}, \rho_{k',m'}\rangle = \sum_{l,l' \in Z_p} w_m^{(k)}[l]\ w_{m'}^{(k')}[l']\ \langle \varphi_{k,l}, \varphi_{k',l'}\rangle.$$

Using properties of lines in the finite geometry Z_p^2, it is easy to verify that

$$\langle \varphi_{k,l}, \varphi_{k',l'}\rangle = \begin{cases} 1 & \text{if } k = k', l = l' \\ 0 & \text{if } k = k', l \ne l' \\ 1/p & \text{if } k \ne k' \end{cases} \quad (28)$$

Thus, when the two FRIT basis functions have the same direction, $k = k'$, then

$$\langle \rho_{k,m}, \rho_{k,m'}\rangle = \sum_{l \in Z_p} w_m^{(k)}[l]\ w_{m'}^{(k)}[l] = \delta[m - m'].$$

So the orthogonality of these FRIT basis functions comes from the orthogonality of the basis $\left\{w^{(k)} : m \in Z_p\right\}$. In particular, we see that $\rho_{k,m}$ have unit norm. Next, for the case when the two FRIT basis functions have different directions, $k \ne k'$, using (28) we obtain

$$\langle \rho_{k,m}, \rho_{k',m'}\rangle = \frac{1}{p} \sum_{l,l' \in Z_p} w_m^{(k)}[l]\ w_{m'}^{(k')}[l']$$
$$= \frac{1}{p}\left(\sum_{l \in Z_p} w_m^{(k)}[l]\right)\left(\sum_{l' \in Z_p} w_{m'}^{(k')}[l']\right).$$

In this case, if either m or m' is non-zero, e.g. $m \ne 0$, then using the *Condition Z* of these bases, $\sum_{l \in Z_p} w_m^{(k)}[l] = 0$, it implies $\langle \rho_{k,m}, \rho_{k',m'}\rangle = 0$.

Finally, note that $\bigcup_l L_k(l) = Z_p^2$, for all directions k (see (10)). So, together with the assumption that $w_0^{(k)}$ are constant functions, we see that all of the FRIT basis functions $\rho_{k,0}$, $(k = 0, 1, \ldots, p)$ correspond to the mean of the input image so we only need to keep one of them (in any direction), which is denoted as ρ_0. The proof is now complete. ∎

Remark 2: 1. An intuition behind the above result is that at each level of the DWT decomposition applied on the FRAT projections, all of the non-orthogonality and redundancy of the FRAT is pushed into the scaling coefficients. When the DWT's are taken to the maximum number of levels then all of the remaining scaling coefficients at different projections are the same, hence we can drop all but one of them. The result is an orthonormal FRIT.

2. We prove the above result for the general setting where different transforms can be applied on different FRAT projections. The choice of transforms can be either adaptive, depending on the image, or pre-defined. For example, one could employ an adaptive wavelet packet scheme independently on each projection. The orthogonality holds as long as the "all lowpass" branch of the general tree-structured filter bank is decomposed to a single coefficient. All other branches would contain at least one highpass filter thus leading to zero-mean basis functions.

3. Furthermore, due to the "wrap around" effect of the FRAT, some of its projections could contain strong periodic components so that a more oscillated basis like the DCT might be more efficient. Also note that from Theorem 1, if we apply the 1-D Fourier transform on all of the FRAT projections then we obtain the 2-D Fourier transform. For convenience, we still use the term FRIT to refer to the cases where other transforms than the DWT might be applied to some of the FRAT projections.

To gain more insight into the construction for the orthogonal FRIT basis, Figure 8 illustrates a simple example of the transform on a 2×2 block using the Haar wavelet. In this case, the FRIT basis is the same as the 2-D Haar wavelet basis, as well as the 2-D discrete Fourier basis.
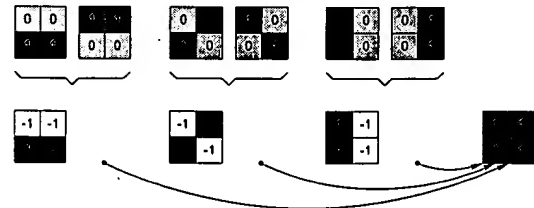

Fig. 8. Illustration on the contraction of orthogonal FRIT basis for a 2×2 block using the Haar wavelet. *Upper:* Basis images for the FRAT. *Lower:* Basis images for the orthogonal FRIT. These images are obtained by taking the (scaled) Haar transform for each pair (corresponding to one projection) of the FRAT basis images. The constant image results from all projections and thus we can drop all but one of them.

V. Variations on the Theme

A. Folded FRAT and FRIT

The FRAT in the previous sections is defined with a periodic basis over Z_p^2. This is equivalent to applying the transform to a periodization of the input image f. Therefore relatively large amplitude FRAT coefficients could result due to the possible discontinuities across the image borders. To overcome this problem, we propose a similar strategy as in the block cosine transform by extending the image symmetrically about its borders [3].
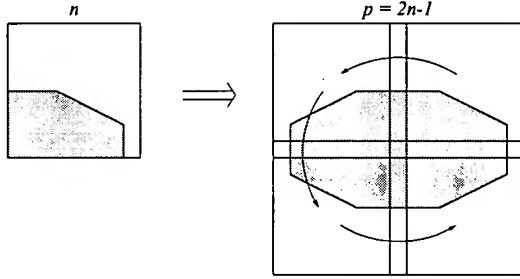

Fig. 9. Extending the image symmetrically about its borders in order to reduce the discontinuities across the image borders due to the periodization.

Given that p is a prime number and $p > 2$, then p is odd and can be written as $p = 2n - 1$. Consider an $n \times n$ input image $f[i,j]$, $0 \le i,j < n$. Fold this image with respect to the lines $i = 0$ and $j = 0$ to produce a $p \times p$ image $\check{f}[i,j]$, in which (also see Figure 9)

$$\check{f}[i,j] = f[|i|,|j|], \quad -n < i,j < n. \tag{29}$$

The periodization of $\check{f}[i,j]$ is symmetric and continuous across the borders of the original image, thus eliminating the jump discontinuity that would have resulted from the periodic extension of $f[i,j]$. Applying the FRAT to the $\check{f}[i,j]$ results in $p(p+1)$ transform coefficients. Notice the new range for the pixel indices of the image $\check{f}[i,j]$. We will show that the FRAT coefficients of $\check{f}[i,j]$ exhibit certain symmetry properties so that the original image can be perfectly reconstructed by keeping exactly n^2 coefficients.

Consider the 2-D DFT of $\check{f}[i,j]$

$$\check{F}[u,v] = \frac{1}{p} \sum_{-n<i,j<n} \check{f}[i,j] W_p^{ui+vj}.$$

Using the symmetry property of $\check{f}[i,j]$ in (29), we obtain

$$\check{F}[u,v] = \check{F}[|u|,|v|].$$

Theorem 1 shows that the FRAT $\check{r}_{a,b}[t]$, $(-n < t < n)$ of $\check{f}[i,j]$ can be computed from the inverse 1-D DFT as

$$\check{r}_{a,b}[t] = \frac{1}{\sqrt{p}} \sum_{-n<w<n} \check{R}_{a,b}[w] W_p^{-wt},$$

where $\check{R}_{a,b}[w] = \check{F}[aw,bw]$. The symmetry of $\check{F}[u,v]$ thus yields

$$\check{R}_{a,b}[w] = \check{R}_{a,b}[|w|] \quad \text{and} \tag{30}$$

$$\check{R}_{a,b}[w] = \check{R}_{|a|,|b|}[w]. \tag{31}$$

From (30) we have $\check{r}_{a,b}[t] = \check{r}_{a,b}[|t|]$ or each projection $\check{r}_{a,b}[t]$ is symmetric about $t = 0$, and (31) reveals the duplications among those projections. In fact, with the set of optimal normal vectors in (20), except for two projections indexed by $(1,0)$ and $(0,1)$ (the vertical and horizontal projections, respectively) all other projections have an identical twin. By removing those duplications we are left with $2 + (p-2)/2 = n + 1$ projections. For example, we can select the set of $n + 1$ independent projections as the ones with normal vectors in the first quadrant (refer to Figure 6). Furthermore, as in (10), the redundancy among the projections of the folded FRAT can be written as

$$\check{r}_{a_k^\star,b_k^\star}[0] + 2 \sum_{t=1}^{n-1} \check{r}_{a_k^\star,b_k^\star}[t] = \frac{1}{\sqrt{p}} \sum_{-n<i,j<n} \check{f}[i,j]. \tag{32}$$

The next proposition summarizes the above results.

Proposition 3: The image $f[i,j]$ can be perfectly reconstructed from the following $n^2 - 1$ coefficients:

$$\check{r}_{a_k^\star,b_k^\star}[t] \quad \text{such that } \mathcal{C}_p(a_k^\star) \ge 0 \text{ and } 0 < t < n, \tag{33}$$

and the mean of the image $\check{f}[i,j]$.

To gain better energy compaction, the mean should be subtracted from the image $\check{f}[i,j]$ previous to taking the FRAT. The set of independent coefficients in (33) is referred as the folded FRAT of the image $f[i,j]$.

However, orthogonality might be lost in the folded FRIT (resulting from applying 1-D DWT on $n + 1$ projections of the folded FRAT), since the basis functions from a same direction of the folded FRAT could have overlap. Nevertheless, if we loosen up the orthogonality constraint, then by construction, the folded FRAT projections $(\check{r}_{a_k^\star,b_k^\star}[t] : 0 < t < n)$ are symmetric with respect to $t = 0$ and $t = n - 1/2$. This allows the use of folded wavelet transform with biorthogonal symmetric wavelets [27] or orthogonal symmetric IIR wavelets [28]. We anticipate the folded FRIT has potential in block transforms (i.e. dividing the image into small blocks and applying FRIT to each block) where the border effect is more serious, and plan report the results in a forthcoming paper.

B. Multilevel FRIT's

In the FRIT scheme described previously, multiscale comes from the 1-D DWT. As a result, at each scale, there is a large number of directions, which is about the size of the input image. Moreover, the basis images of the FRIT have long support, which extend over the whole image.

Here we propose a different scheme where the number of directions can be controlled, and the basis functions have smaller support. Assume that the input image has the size $n \times n$, where $n = p_1 p_2 \ldots p_J q$ and p_i are prime numbers. First, we apply the orthonormal FRIT to $n_1 \times n_1$ non-overlapping subimages of size $p_1 \times p_1$, where $n_1 = p_2 \ldots p_J q$. Each sub-image is transformed into $p_1^2 - 1$ "detail" FRIT coefficients plus a mean value. These mean values form an $n_1 \times n_1$ coarse approximate image of the original one. Then the process can be iterated on the coarse version up to J levels. The result is called as multilevel FRIT (MFRIT).

At each level, the basis functions for the "detail" MFRIT coefficients are obviously orthogonal within each block, and also with other blocks since they do not overlap. Furthermore, these basis functions are orthogonal with the constant function on their block, and thus orthogonality holds across levels as well. Consequently, the MFRIT is an orthonormal transform.

By collecting the MFRIT coefficients into groups depending on their scales and directions, we obtain a subband-like decomposition with J scales, where level i has p_i directions. When $p_i = 2$, the orthonormal FRIT using the Haar DWT is the same as the 2×2 Haar DWT (see Figure 8). Therefore the MFRIT scheme includes the multilevel 2-D Haar DWT. In general, when $p_i > 2$, the MFRIT offers more directions than the 2-D DWT and can be useful in certain applications such as texture analysis.

## VI. NUMERICAL EXPERIMENTS

A. Non-linear Approximation

Following the study of the efficiency of the ridgelet transform in the continuous domain using the truncated Gaussian functions [6], we first perform numerical comparison on a 256×256 image of the function: $f(x_1, x_2) = 1_{\{x_2 < 2x_1 + 0.5\}} e^{-x_1^2 - x_2^2}$ (see Figure 10(a)), using four 2-D transforms: DCT, DWT, FRAT and FRIT. The comparison is evaluated in terms of the non-linear approximation power, i.e. the ability of reconstructing the original image, measured by signal-to-noise ratios (SNR's), using the N largest magnitude transform coefficients. For the FRAT and FRIT, we extend the image size to the next prime number, 257, by replicating the last pixel in each row and column. We use the orthogonal *Symmlet* wavelet with 4 vanishing moments [24] for both the DWT and the FRIT.

Our initial experiments indicate that in order to achieve good results, it is necessary to apply strong oscillated bases to certain FRAT projections to handle to the "wrap around" effect (refer to the remarks at the end of Section IV). For images with linear singularities, we find that in the FRAT domain, most of the image energy and singularities are contained in the projections with the *least* "wrap around" (see Figure 13(b)). Therefore, without resorting to adaptive methods, we employ a simple, predefined scheme where the DWT is only applied to the projections with $\|(a_k^*, b_k^*)\| \leq D$, while the remaining projections use the DCT. We use $D = 3$ in our experiments, which means in the tested FRIT, only 16 FRAT projections are represented by the DWT. Although the this FRIT contains most of Fourier-type basis functions, due to the concentration of energy mentioned above, the resulting nonlinear approximation images are mainly composed of the ridgelet-type functions that fit around the linear edge.

Figure 10(b) display the comparison results. We omit the FRAT since its performance is much worse than the others. Clearly the FRIT achieves the best result, as expected from the continuous theory. Furthermore, the new ordering of the FRAT coefficients is crucial for the FRIT in obtaining good performance.
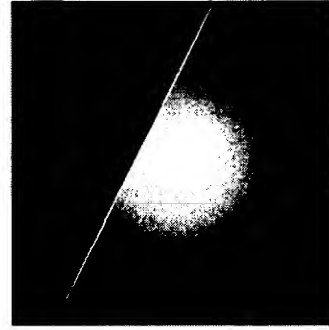
(a)
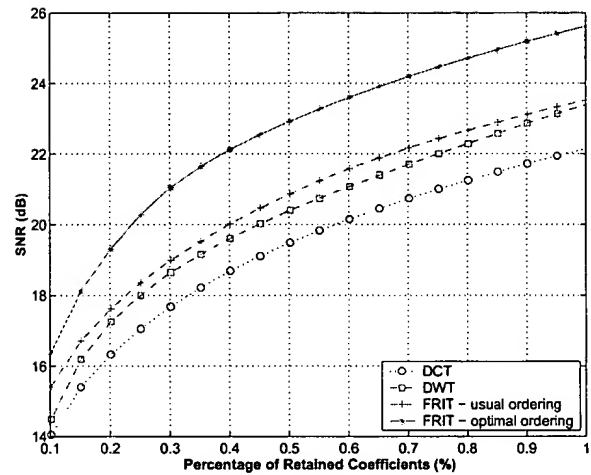
(b)

Fig. 10. (a) Test image: a truncated Gaussian image of size 256×256 that represents the function $f(x_1, x_2) = 1_{\{x_2 < 2x_1 + 0.5\}} e^{-x_1^2 - x_2^2}$. (b) Comparison of non-linear approximations using four different 2-D transforms: DCT, DWT, FRIT with usual ordering and FRIT with optimal ordering.
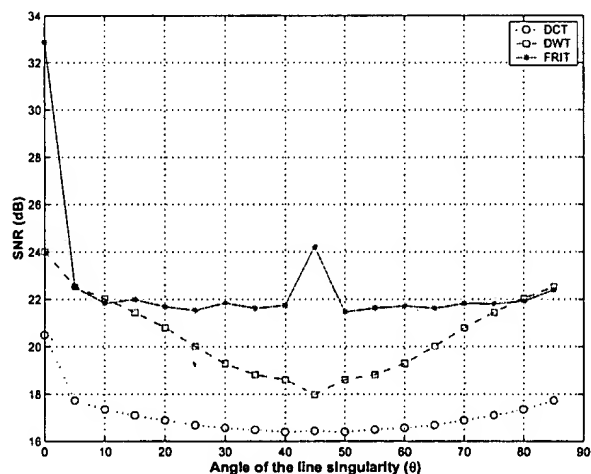

Fig. 11. Non-linear approximation comparison at different orientation of the line singularity in the truncated Gaussian images $f_\theta(x_1, x_2) = 1_{\{x_1 \cos\theta + x_2 \sin\theta < 0.3\}} e^{-x_1^2 - x_2^2}$. In each case, we keep the most 0.5% significant coefficients.
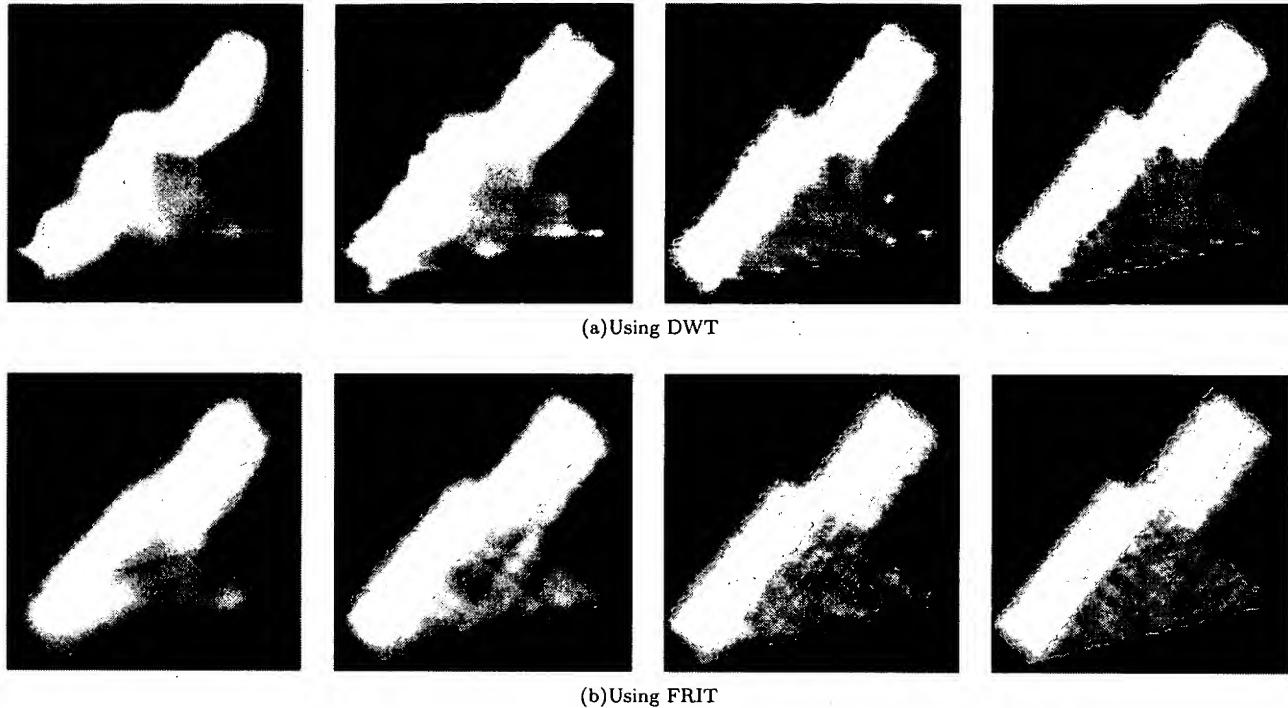
(a)Using DWT

(b)Using FRIT

Fig. 12.   From left to right, reconstructed images from the 32, 64, 128 and 256 most significant coefficients of the DWT and FRIT, out of 65536 coefficients.

We then compare the performance where the singular-ity line varies its orientation.   Consider the truncated Gaussian image again, using the function $f_\theta(x_1, x_2) = 1_{\{x_1 \cos \theta + x_2 \sin \theta < 0.3\}} e^{-x_1^2 - x_2^2}$.   Due to the circular symme-try, we only need to consider $0 \le \theta < 90°$.   Figure 11 shows the results where the FRIT (with optimal ordering) con-sistently outperforms both the DWT, more than 2 dB on the average, as well as the DCT.

Our next test is a real image of size 256×256 with straight edges.   Figure 12 shows the images obtained from non-linear approximation using the DWT and FRIT. As can be seen, the FRIT correctly picks up the edges using the first few significant coefficients and produces visually better approximated images. But let us point out that even this simple test image can not be represented as a summa-tion of a few "global" linear singularities (like the Gaussian truncated images), and thus it is *not* in the optimal class of the ridgelet transform.

To gain an insight into the FRIT, Figure 13(a) shows the top five FRAT projections for the "object" image that con-tain most of the energy, measured in the l_2-norm.   Those projections correspond to the directions that have discon-tinuities across, plus the horizontal and vertical directions. Therefore, we see that at first the FRAT compacts most of the energy of the image into a few projections (see Fig-ure 13(b)), where the linear discontinuities create "jumps". Next, taking the 1-D DWT on those projections, which are mainly smooth, compacts the energy further into a few FRIT coefficients.·

B. Image Denoising

The motivation for the FRIT-based image denoising method is that in the FRIT domain, linear singularities of the image are represented by a few large coefficients, whereas randomly located noisy singularities are unlikely to produce significant coefficients.   By contrast, in the DWT domain, both image edges and noisy pixels produce simi-lar amplitude coefficients.   Therefore, a simple threshold-ing scheme for FRIT coefficients can be very effective in denoising images that are piecewise smooth away from sin-gularities along straight edges.

We consider a simple case where the original image is contaminated by an additive zero-mean Gaussian white noise of variance σ^2.   With an orthogonal FRIT, the noise in the transform domain is also Gaussian white of the same variance.   Therefore it is appropriate to apply the thresh-olding estimators that were proposed in [29] to the FRIT coefficients.   More specifically, our denoising algorithm con-sists of the following steps:

Step 1: Applying FRIT to the noisy image.
Step 2: Hard-thresholding of FRIT coefficients with the universal threshold $T = \sigma \sqrt{2 \log N}$ where $N = p^2$ pixels.
Step 3: Inverse FRIT of the thresholded coefficients.
For an image which is smooth away from linear singulari-ties, edges are visually well restored after Step 3.   However due to the periodic property of the FRIT, strong edges sometimes create "wrap around" effects which are visible in the smooth regions of the image.   In order to overcome this problem, we optionally employ a 2-D adaptive filtering step.
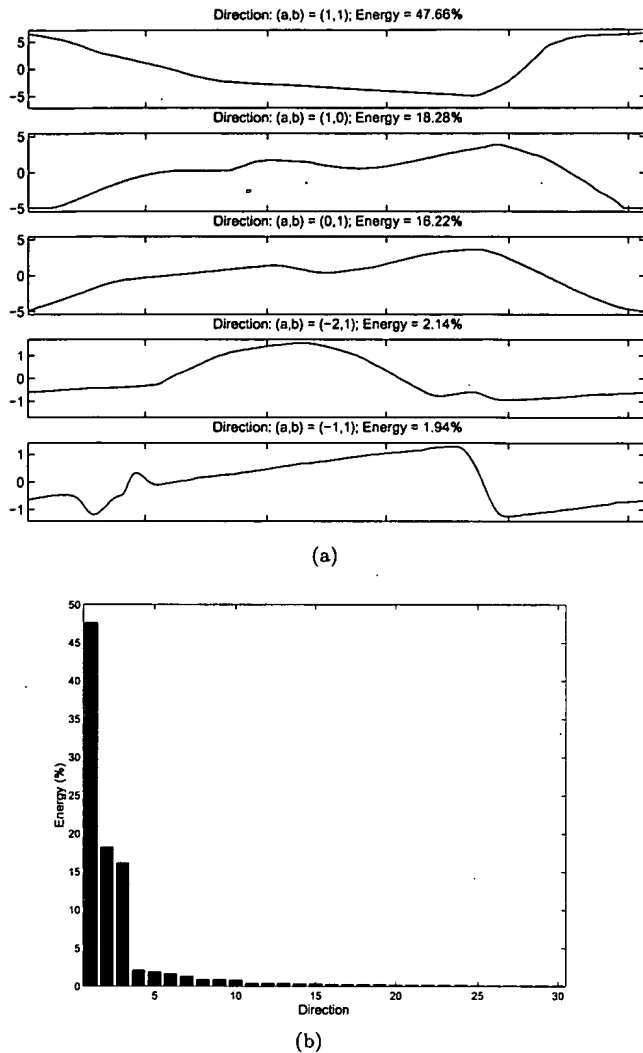
(a)

(b)

Fig. 13. (a) Top five FRAT projections of the "object" image that contain most of the energy. (b) Distribution of total input image energy among FRAT projections. Only the top 30 projections are shown in the descending order.
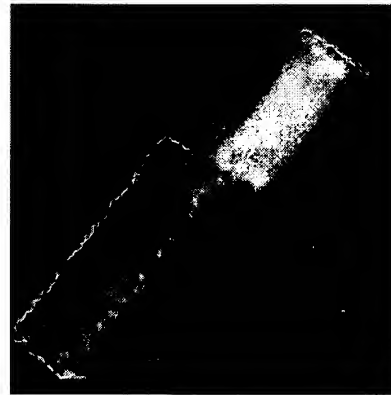

(a)Using DWT; SNR = 19.78 dB.

(b)Using FRIT; SNR = 19.67 dB

(c)Using FRIT and Wiener filter; SNR = 21.07 dB.

Fig. 14. Comparison of denoising on the "object" image.

Step 4: (Optional) Adaptive Wiener filtering to reduce the "wrap around" effect.

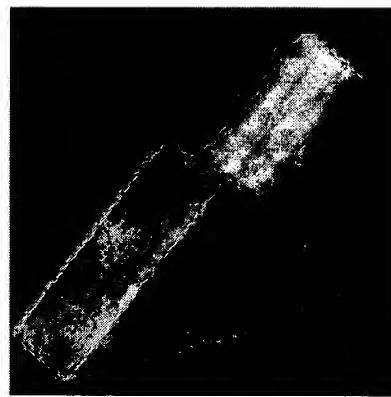In some cases, this can enhances the visual appearance of the restored image.

The above FRIT denoising algorithm is compared with the analogous wavelet hard-thresholding method using the same threshold value. Figure 14 shows the denoising results on the real image. The FRIT is clearly shown to be more effective than the DWT in recovering straight edges, as well as in term of SNR's.

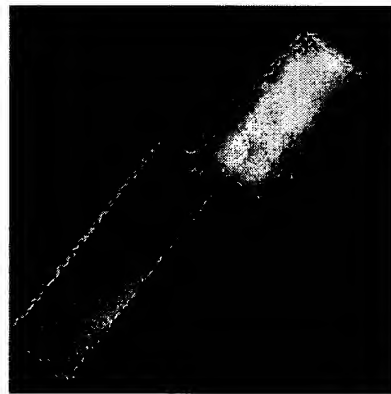## VII. CONCLUSION AND DISCUSSION

We presented a new family of discrete orthonormal transforms for images based on the ridgelet idea. Owning to orthonormality, the proposed ridgelet transform is self-inverting – the inverse transform uses the same algorithm as the forward transform – and has excellent nu-

merical stability. Experimental results indicate that the FRIT offers an efficient representation for images that are smooth away from line discontinuities or straight edges. A Matlab code implementing the transforms and experiments in this paper is available at an author's Web page www.ifp.uiuc.edu/~minhdo.

However, it is important to emphasize that the ridgelet transform is only suited for discontinuities along straight lines. For complex images, where edges are mainly along

curves and there are texture regions (which generate point discontinuities), the ridgelet transform is not optimal. Therefore, a more practical scheme in employing the ridgelet transform is to first utilize a quad-tree division of images into suitable blocks where edges look straight and then apply the discrete ridgelet transform to each block. Another scheme is to use the ridgelet transform as the building block in a more localized construction such as the *curvelet* transform [30].

Acknowledgment The authors thank Prof. Attila Kuba and Prof. Gabor Herman for pointing us the references [20], [21], Pier Luigi Dragotti and Rahul Shukla of EPFL for many stimulating discussions, and the reviewers for their constructive remarks.

APPENDIX

I. ORTHOGONAL WAVELET TRANSFORM FOR NON DYADIC LENGTH SIGNALS

In the construction of the orthonormal FRIT, we need wavelet bases for signals of prime length p. In addition, those bases have to satisfy the *Condition Z* in Lemma 1. Let $n = 2^J$ be the nearest dyadic number to p that is smaller than or equal to p. Suppose that $p - n$ is small, then one simple way of taking the wavelet transform on a sequence of p samples is to apply the usual wavelet transform on the first n samples and then extend it to cover the remaining $p - n$ samples.

Let $\{v_m : m \in Z_n\}$ to be the basis vectors of an orthonormal wavelet transform of length n with J decomposition levels. We assume periodic extension is used to handle the boundary. Suppose that v_0 corresponds to the single scaling coefficient or the mean value, then all other vectors must have zero mean (see Lemma 1). Denote $c^{\{k\}}$ be the vector with k entries, all equal to c. Consider the following p vectors defined in $\mathbb{R}^p$

$$
\begin{aligned}
w_0 &= \left(1^{\{p\}}\right) / s_0 \\
w_1 &= \left(1^{\{p-1\}}, -p+1\right) / s_1 \\
w_2 &= \left(1^{\{p-2\}}, -p+2, 0\right) / s_2 \\
&\cdots \\
w_{p-n} &= \left(1^{\{p-n\}}, -p+n, 0^{\{n-1\}}\right) / s_{p-n} \\
w_{p-n+1} &= \left(v_1, 0^{\{p-n\}}\right) \\
&\cdots \\
w_{p-1} &= \left(v_{n-1}, 0^{\{p-n\}}\right).
\end{aligned}
$$

Here s_k is the scale factor such that $\|w_k\| = 1$. The orthogonality of the new set $\{w_k : k \in Z_p\}$ can be easily verified given the fact that $\{v_m : 1 \leq m < n\}$ are orthonormal vectors with zero mean. Therefore, $\{w_k : k \in Z_p\}$ is an orthonormal basis for $\mathbb{R}^p$ that satisfies the *Condition Z*. For a length p input vector $x = (x_0, x_1, \ldots, x_{p-1})$, the transform coefficients correspond to w_k, where $p - n \leq k \leq p - 1$, can be computed efficiently using the usual DWT with J levels on the first n samples $x' = (x_0, x_1, \ldots, x_{n-1})$. The last scaling coefficient is then replaced by $p - n + 1$ coefficients

corresponding to the basis vectors w_k, $k = 0, \ldots, p - n$. Thus the new basis in $\mathbb{R}^p$ also has fast transforms.
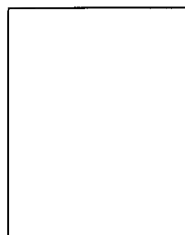
REFERENCES

[1] M. Vetterli and J. Kovačević, *Wavelets and Subband Coding*, Prentice-Hall, Englewood Cliffs, NJ, 1995.

[2] D. L. Donoho, M. Vetterli, R. A. DeVore, and I. Daubechies, "Data compression and harmonic analysis," *IEEE Trans. Inform. Th.*, vol. 44, no. 6, pp. 2435–2476, October 1998.

[3] S. Mallat, *A Wavelet Tour of Signal Processing*, Academic Press, 2nd edition, 1999.

[4] K. R. Rao and P. Yip, *Discrete Cosine Transform: Algorithms, Advantages, Applications*, Academic Press, 1990.

[5] E. J. Candès, *Ridgelets: Theory and Applications*, Ph.D. thesis, Department of Statistics, Stanford University, 1998.

[6] E. J. Candès and D. L. Donoho, "Ridgelets: a key to higher-dimensional intermittency?," *Phil. Trans. R. Soc. Lond. A.*, pp. 2495–2509, 1999.

[7] S. R. Deans, *The Radon Transform and Some of Its Applications*, John Wiley & Sons, 1983.

[8] D. L. Donoho and M. R. Duncan, "Digital curvelet transform: strategy, implementation and experiments," in *Proc. Aerosense 2000, Wavelet Applications VII.* SPIE, 2000, vol. 4056, pp. 12–29.

[9] J. L. Starck, E. J. Candès, and D.L. Donoho, "The curvelet transform for image denoising," *IEEE Trans. Image Proc.*, vol. 11, pp. 670–684, Jun. 2002.

[10] A. Averbuch, R. R. Coifman, D. L. Donoho, M. Israeli, and J. Waldén, "Fast slant stack: A notion of Radon transform for data in a Cartesian grid which is rapidly computable, algebraically exact, geometrically faithful and invertible," Tech. Rep., 2001, Preprint, http://www.math.tau.ac.il/~amir1/.

[11] E. D. Bolker, "The finite Radon transform," in *Integral Geometry (Contemporary Mathematics, Vol. 63)*, S. Helgason R. L. Bryant, V. Guillemin and R. O. Wells Jr., Eds., pp. 27–50. 1987.

[12] S. Mallat and W. L. Hwang, "Singularity detection and processing with wavelets," *IEEE Transactions on Information Theory, Special Issue on Wavelet Transforms and Multiresolution Signal Analysis*, vol. 38, no. 2, pp. 617–643, March 1992.

[13] G. T. Herman, *Image Reconstruction from Projections: The Fundamentals of Computerized Tomography*, Academic Press, 1980.

[14] A. Rosenfeld and A. C. Kak, *Digital Picture Processing*, Academic Press, 2nd edition, 1982.

[15] R. M. Mersereau and A. V. Oppenheim, "Digital reconstruction of multidimensional signals from projections," *Proc. of IEEE*, vol. 62, no. 10, pp. 1319–1338, Oct 1974.

[16] G. Beylkin, "Discrete Radon transform," *IEEE Trans. Acoust. Speech Sig. Proc.*, vol. 35, pp. 162–172, 1987.

[17] J. L. C. Sanz, E. B. Hinkle, and A. K. Jain, *Radon and Projection Transform-Based Computer Vision*, Springer Verlag, 1988.

[18] B. T. Kelley and V. K. Madisetti, "The fast discrete Radon transform – I: Theory," *IEEE Trans. on Image Proc.*, vol. 2, pp. 382–400, Jul 1993.

[19] I. Gertner, "A new efficient algorithm to compute the two-dimensional discrete Fourier transform," *IEEE Trans. Acoust. Speech Sig. Proc.*, vol. 36, pp. 1036–1050, Jul 1988.

[20] F. Matúš and J. Flusser, "Image representation via a finite Radon transform," *IEEE Trans. Pattern Anal. Machine Intell.*, vol. 15, no. 10, pp. 996–1006, Oct 1993.

[21] P. M. Salzberg and R. Figueroa, "Tomography on the 3D-torus and crystals," in *Discrete Tomography: Foundations, Algorithms and Applications*, G. T. Herman and A. Kuba, Eds., pp. 417–434. Birkhäuser, 1999.

[22] N. D. Vvedenskaya and S. G. Gindikin, "Discrete Radon transform and image reconstruction," in *Mathematical problems of tomography (Translations of mathematical monographs, Vol. 81)*, I. M. Gelfand and S. G. Gindikin, Eds., pp. 141–188. American Mathematical Society, 1990.

[23] R. Lidl and H. Niederreiter, *Introduction to Finite Fields and Their Applications*, Cambridge University Press, revised edition, 1994.

[24] I. Daubechies, *Ten Lectures on Wavelets*, SIAM, Philadelphia, PA, 1992.

[25] R. A. Horn and C. R. Johnson, *Matrix Analysis*, Cambridge University Press, 1985.

[26] V. K. Goyal, J. Kovačević, and J. A. Kelner, "Quantized frame expansions with erasures," *Applied and Computational Harmonic Analysis*, vol. 10, no. 3, pp. 203–233, May 2001.

[27] C. M. Brislawn, "Classification of nonexpansive symmetric extension transforms for multirate filter banks," *Applied and Computational Harmonic Analysis*, vol. 3, pp. 337–357, 1996.

[28] C. Herley and M. Vetterli, "Wavelets and recursive filter banks," *IEEE Trans. Signal Proc.*, vol. 41, no. 8, pp. 2536–2556, August 1993.

[29] D. Donoho and I. Johnstone, "Ideal spatial adaptation via wavelet shrinkage," *Biometrika*, pp. 425–455, December 1994.

[30] E. J. Candès and D. L. Donoho, "Curvelets – a suprisingly effective nonadaptive representation for objects with edges," in *Curve and Surface Fitting*, A. Cohen, C. Rabut, and L. L. Schumaker, Eds., Saint-Malo, 1999, Vanderbilt University Press.

Minh N. Do was born in Thanh Hoa, Vietnam, in 1974. He received the B.Eng. degree in computer engineering (with first class honors) from the University of Canberra, Australia, in 1997, and the Dr.Sci. degree in communication systems from the Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland, in 2001.

Since 2002, he has been an Assistant Professor with the Department of Electrical and Computer Engineering and a Research Assistant Professor with the Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign. His research interests include wavelets and harmonic analysis, multirate systems, image and multidimensional signal processing, and visual information representation.

Dr. Do received a Silver Medal from the 32nd International Mathematical Olympiad in Sweden (1991) and a University Medal from the University of Canberra (1997).

Martin Vetterli received the Dipl. El.-Ing. degree from ETH Zürich (ETHZ), Switzerland, in 1981, the MS degree from Stanford University in 1982, and the Doctorat ès Science degree from EPF Lausanne (EPFL), Switzerland, in 1986.

He was a Research Assistant at Stanford and EPFL, and has worked for Siemens and AT&T Bell Laboratories. In 1986, he joined Columbia University in New York where he was last an Associate Professor of Electrical Engineering and co-director of the Image and Advanced Television Laboratory. In 1993, he joined the University of California at Berkeley where he was a Professor in the Dept. of Electrical Engineering and Computer Sciences until 1997, and holds now an Adjunct Professor position. Since 1995, he is a Professor of Communication Systems at EPF Lausanne, Switzerland, where he chaired the Communications Systems Division (1996/97), and heads of the Audio-Visual Communications Laboratory. He held visiting positions at ETHZ (1990) and Stanford (1998).

He is a fellow of the IEEE, a member of SIAM, and was the Area Editor for Speech, Image, Video, and Signal Processing of the IEEE Transactions on Communications. He is also on the editorial boards of Annals of Telecommunications, Applied and Computational Harmonic Analysis and The Journal of Fourier Analysis and Applications. He received the Best Paper Award of EURASIP in 1984 for his paper on multidimensional subband coding, the Research Prize of the Brown Bovery Corporation (Switzerland) in 1986 for his doctoral thesis, the IEEE Signal Processing Society's Senior Award in 1991 and in 1996 (for papers with D.LeGall and K.Ramchandran, respectively). He received the Swiss National Latsis Prize in 1996, the SPIE Presidential award in 1999, and the IEEE Signal Processing Technical Achievement Award in 2001. He is a member of the Swiss Council on Science and Technology. Since 2001, he directs the National Competence Center in Research on mobile information and communication systems (www.terminodes.org).

He was a plenary speaker at various conferences (e.g. 1992 IEEE ICASSP) and is the co-author, with J.Kovacevic, of the book **Wavelets and Subband Coding** (Prentice-Hall, 1995). He has published about 85 journal papers on a variety of topics in signal and image processing and holds 7 patents.

His research interests include wavelets, multirate signal processing, computational complexity, signal processing for telecommunications, digital video processing and compression and wireless video communications.
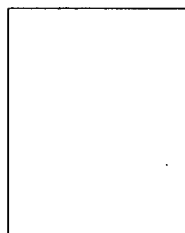
EPFL

Audiovisual Communications Laboratory

School of Computer & Commn. Sciences

HOME PEOPLE RESEARCH TEACHING STUDENTS PUBLICATIONS TECH. TRANSFER MISC. INFO DEMOS RESOURCES

Journal Papers | Conference Papers | Technical Reports and PhD Theses |

The status of this publication list evolves continuously.
Please refer to the member's homepage for (hopefully) updated list.
Copyright holders include the IEEE and SPIE. Available for personal, non-commercial purposes only.

2003:

- R. Shukla, P. L. Dragotti, M. N. Do, M. Vetterli. " Rate-distortion optimized tree structured compression algorithms for piecewise smooth image",,IEEE Transactions on Image Processing, Jan. 2003, submitted.
- R. Cristescu, S. D. Servetto. "Queues under feedback control",submitted.
- I. Maravic, M. Vetterli. "Exact sampling results for classes of parametric non-bandlimited 2-D signals", to appear in IEEE Transactions on Signal Processing.

2002:

- M. Gastpar, B. Rimoldi, M. Vetterli. "To code or not to code: lossy source-channel communication revisited",,IEEE Transactions on Information Theory, Jun. 2002, submitted.
- S. Horbelt, M. Liebling and M. Unser. "Discretisation of the Radon transform and its inverse by spline convolutions",, IEEE Transaction on Medical Imaging, vol. 21, no. 4, pp. 363-376, Apr. 2002.
- M. Do and M. Vetterli. "Wavelet-based texture retrieval using generalized Gaussian density and Kullback-Leibler distance",, IEEE Transaction on Image Processing, vol. 11, no. 2, pp. 146-158, Feb. 2002.
- M. Vetterli, P. Marziliano and T. Blu. "Sampling signals with finite rate of innovation",, Signal Processing, IEEE Transactions on, vol. 50 no. 6, June 2002, pp. 1417 -1428.
- P. L. Dragotti and M. Vetterli. "Wavelet Footprints: Theory, Algorithms and Applications",, submitted to IEEE Trans. on Signal Processing. accepted, Dec. 2002, revised June 2002.
- P. L. Dragotti, S. Servetto and M. Vetterli. "Filter Banks for Multiple Description Coding: Analysis and Synthesis",, IEEE Trans. on Information Theory, vol. 48(7), pp. 2036-2052, July 2002.
- J. Kovacevic, P. L. Dragotti and V. K. Goyal. "Filter Bank Frame Expansions with Erasures",, IEEE Trans. on Information. Theory, special issue in Honor of Aaron D. Wyner, vol. 48(6), pp. 1439-1450, June 2002.
- M. Gastpar. "The Wyner-Ziv problem with multiple sources",, EPFL I&C Technical Report IC/2002/36, Lausanne, Switzerland, Jun. 2002, and submitted to IEEE Transaction on Information Theory.
- M. Do and M. Vetterli. "Rotation invariant texture characterization and retrieval using steerable wavelet-domain hidden Markov models",, IEEE Transaction on Multimedia, Jun. 2002, in press.
- M. Do and M. Vetterli. "The finite ridgelet transform for image representation",, IEEE Transactions on Image Processing, Jun. 2002, in press.

2001:

- Z.Cvetkovic, M. Vetterli. "On simple oversampled A/D conversion in $L^2(R)$",, Information Theory, IEEE Transaction on, vol. 47, no. 1, Jan. 2001, pp. 59-73.
- J.P. Hubaux, T. Gross, J.Y. Le Boudec and M. Vetterli. "Toward self-organized mobile ad hoc networks: The terminodes project",, IEEE Communications Magazine, vol. 39, no. 1, Jan. 2001.
- M. Podolsky, McCanne S, Vetterli M (2001). "Soft ARQ for layered streaming media",, Special Issue on Multimedia Signal Processing for the Journal of VLSI Signal Processing Systems for Signal, Image and Video Technology, Kluwer Academic Publishers, Feb. 2001.

2000:

- S. G. Chang, B. Yu and M. Vetterli. "Spatially adaptive wavelet thresholding with context modeling for image denoising",, Image Processing, IEEE Transactions on , vol. 9, no. 9 , Sept. 2000, page(s): 1522 -1531.
- S. G. Chang, B. Yu and M. Vetterli. "Adaptive wavelet thresholding for image denoising and compression",, Image Processing, IEEE Transactions on , vol. 9, no. 9 , Sept. 2000, page(s): 1532 -1546.
- S. G. Chang, B. Yu and M. Vetterli. "Wavelet thresholding for multiple noisy image",, Image Processing, IEEE Transactions on , vol. 9, no. 9 , Sept. 2000, page(s): 1631 -1635.
- V. K. Goyal, J. Zhuang and M. Vetterli. "Transform coding with backwards adaptive updates",, Information Theory, IEEE Transactions on , vol. 46, no. 4 , July 2000, Page(s): 1623 -1633.
- P. Marziliano and M. Vetterli. "Reconstruction of irregularly sampled discrete-time bandlimited signals with unknown sampling locations",, Signal Processing, IEEE Transactions on , vol. 48, no. 12 , Dec. 2000, Page(s): 3462 -3471.
- P. Prandoni and M. Vetterli. "R/D optimal linear prediction",, IEEE Transaction on Speech Audio Processing, vol. 8, No. 6, pp. 646-655, 2000.
- S. D. Servetto, K. Ramchandran, V. A. Vaishampayan and K. Nahrstedt. "Multiple Description Wavelet Based Image Coding",, IEEE Transaction on Image Processing, vol. 9, No. 5, pp. 813-826, 2000.
- S. D. Servetto and K. Nahrstedt. "Broadcast quality video over IP",, to appear in IEEE Transaction on Multimedia, 2000.
- V. A. Vaishampayan, N. J. A. Sloane and S. D. Servetto. "Multiple Description Vector Quantization with Lattice Codebooks: Design and Analysis",, Information Theory, IEEE Transactions on , vol. 47, no. 5 , July 2001, Page(s): 1718

-1734.

1999:

- M. Goodwin and M. Vetterli. **"Matching pursuit and atomic signal models based on recursive filter banks",**, IEEE Transactions on Signal Processing, vol. 47, no. 7, Jul. 1999, pp. 1890 -1902.
- P. Prandoni and M. Vetterli. **"Approximation and Compression of Piecewise Smooth Functions",**, Phil. Transaction R. Soc. Lond. A. vol. 357, no. 1760, pp. 2573-2591, Sep. 1999.
- S. D. Servetto, K. Ramchandran and M. T. Orchard. **"Image Coding based on a Morphological Representation of Wavelet Data",**, IEEE Trans. on Image Processing, vol. 8, no. 9, pp. 1161-1174, Sep. 1999.

1998:

- R. Bernardini and M. Vetterli. **"Discrete- and continuous-time local cosine bases with multiple overlapping",**, IEEE Transaction on Signal Processing, vol. 46, no. 12, pp. 3166-3180, Dec. 1998.
- Z. Cvetkovic and M. Vetterli. **"Error-rate characteristics of oversampled analog-to-digital conversion",**, IEEE Transaction on Information Theory, vol. 44, no. 5, pp. 1961-1964, Sep. 1998.
- Z. Cvetkovic and M. Vetterli. **"Oversampled Filter Banks",**, IEEE Transaction on Signal Processing, vol. 46, no. 5, pp. 1245-1255, May 1998.
- Z. Cvetkovic and M. Vetterli. **"Tight Weyl-Heisenberg frames in $l^2(Z)$",**, IEEE Transaction on Signal Processing, vol. 46, no. 5, pp. 1256-1259, May 1998.
- D. Donoho, M. Vetterli, R. DeVore and I. Daubechies. **"Data compression and harmonic analysis",**, Invited paper, IEEE Transactions on Information Theory, Special Issue, Information Theory: 1948-1998 Commemorative Issue, vol. 44, no. 6, Oct. 1998, pp. 2435-2476. Also reprinted in Information Theory: 50 Years of Discovery, S. Verdu, S. W. McLaughlin, Eds., IEEE Press, 1999, pp. 391-432.
- G. Evangelista and S. Cavaliere. **"Frequency Warped Filter Banks and Wavelet Transform: A Discrete-Time Approach Via Laguerre Expansions",**, IEEE Transaction on Signal Processing, vol. 46, no. 10, pp. 2638-2650, Oct. 1998.
- G. Evangelista and S. Cavaliere. **"Discrete Frequency Warped Wavelets: Theory and Applications",**, IEEE Transaction on Signal Processing, vol. 46, no. 4, pp. 874-885, Apr. 1998.
- V. K. Goyal, M. Vetterli and N. T. Thao. **"Quantized overcomplete expansions in IRN: Analysis, synthesis, and algorithms",**, IEEE Transaction on Information Theory, vol. 44, no. 1, pp. 16-31, Jan. 1998.
- J. Lebrun and M. Vetterli. **"Balanced Multiwavelets Theory and Design",**, IEEE Transactions on Signal Processing, Special issue on Wavelets, vol. 46, no. 4, pp. 1119-1125, Apr. 1998.
- P. Prandoni and M. Vetterli. **"An FIR cascade structure for adaptive linear prediction",**, IEEE Transactions on Signal Processing, vol. 46, no. 9, Sep. 1998, pp. 2566-2571.
- N. T. Thao and M. Vetterli. **"Set theoretic compression with an application to image coding",**, IEEE Transactions on Image Processing, vol. 7, no. 7, Jul. 1998, pp. 1051-1056.

1997:

- S. McCanne, M. Vetterli and Van Jacobson. **"Low-Complexity Video Coding for Reveiver-Driven Layered Multicast",**, IEEE Journal on Selected-Areas in Communications, vol. 15, no. 6, Aug. 1997, pp. 983-1001.
- A. Ortega and M. Vetterli. **"Adaptive scalar quantization without side information",**, IEEE Transactions on Image Processing, vol. 6, no. 5, May 1997, pp. 665-676.
- H. Park, T. Kalker and M. Vetterli. **"Groebner bases and multidimensional FIR multirate systems",**, Multidimensional Systems and Signal Processing, Kluwer Acad. Pub, vol. 8, 1997, pp. 11-30.
- G. DePoli and P. Prandoni. **"Sonological models for timbre characterization",**, Journal of New Music Research, Swets & Zeitlinger, vol. 26, no. 2, Jun. 1997.

1996:

- P. C. Cosman, R. M. Gray and M. Vetterli. **"Vector quantization of image subbands: A survey",**, IEEE Transactions on Image Processing, vol. 5, no. 2, Feb. 1996, pp. 202-225.
- H. Radha, M. Vetterli and R. Leonardi. **"Image Compression Using Binary Space Partitioning Trees",**, IEEE Transactions on Image Processing, vol. 5, no. 12, Dec. 1996, pp. 1610-1624.
- K. Ramchandran, Z. Xiong, K. Asai and M. Vetterli. **"Adaptive transforms for image coding using spatially varying wavelet packets",**, IEEE Transactions on Image Processing, vol. 5, no. 7, July 1996, pp. 1197-1203.
- K. Ramchandran, M. Vetterli and C. Herley. **"Wavelets, subband coding, and best bases",**, invited paper, IEEE Proceedings, Special Issue on Wavelets, vol. 84, no. 4, April 1996, pp. 541-560.
- H. Samhney and S. Ayer. **"Compact Representations of Videos Through Dominant and Multiple Motion Estimation",**, Pattern Analysis and Machine Intelligence, IEEE Transactions on, vol. 18, no. 8, Aug. 1996, pp. 814 -830.
- N. Thao and M. Vetterli. **"Lower Bound on the Mean-Squared Error in Oversampled Quantization of Periodic Signals Using Vector Quantization Analysis",**, IEEE Transactions on Information Theory, vol. 42, no. 2, Mar. 1996, pp. 469-479.

1995:

- Z. Cvetkovic and M. Vetterli. **"Discrete-Time Wavelet Extrema Representation - Design and Consistent Reconstruction",**, IEEE Transactions on Signal Processing, vol. 43, no. 3, Mar. 1995, pp. 681-694.
- J. Hong and M. Vetterli. **"Simple Algorithms for BCH Decoding",**, IEEE Transactions on Communication, vol. 43, no. 8, Aug. 1995, pp. 2324-2333.
- J. Kovacevic and M. Vetterli. **"Nonseparable 2-Dimensional and 3-Dimensional Wavelets",**, IEEE Transactions on Signal Processing, vol. 43, no. 5, May 1995, pp. 1269-1273.
- A. Ortega, M. W. Garrett and M. Vetterli. **"Rate Constraints for Video Transmission over ATM Networks Based on Joint Source/Network Criteria",**, Annales des Télécommunications, vol. 50, no. 7-8, Sep. 1995, pp. 603-616. (invited

paper).

EPFL | Audiovisual Communications Laboratory | School of Computer & Commn. Sciences

HOME PEOPLE RESEARCH TEACHING STUDENTS PUBLICATIONS TECH. TRANSFER MISC. INFO DEMOS RESOURCES

ADDRESS

Laboratoire de Communications Audiovisuelles - LCAV
Faculé Informatique et Communications - I&C
Ecole Polytechnique Federale de Lausanne - EPFL

Audiovisual Communications Laboratory - LCAV
School of Computer and Communication Sciences - I&C
Swiss Federal Institute of Technology, Lausanne - EPFL

EPFL-I&C-LCAV
CH-1015 Lausanne
SWITZERLAND

(+41 21) 693 56 34 (secretary)
(+41 21) 693 11 11 (staff)

(+41 21) 693 43 12

Other useful numbers:
Prof. Martin Vetterli (head): +41 21 693.5698
Jocelyne Plantefol (secretary): +41 21 693.5634

LCAV

I&C

Faculté I&C

EPFL

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Please consult the Map and directions

MISSION

The mission of the Audiovisual Communications Laboratory is to:

- perform basic and applied research in signal processing for communications
- provide undergraduate and graduate teaching of signal processing for communications
- perform technology transfer to established as well as start up companies.

Faculté I&C School of Computer and Communication Sciences

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE **PUBLICATIONS**

English only   EPFL > I&C > Publications

Technical Reports in Computer and Communication Sciences (as from 2002)

Search: [　　　　　　] **Search** Complete list

- Jean-Yves Le Boudec and Slavisa Sarafijanovic
  An Artificial Immune System Approach to Misbehavior Detection in Mobile Ad-Hoc Networks
  2003-09-19 15:29:36 - *Publication's ID:200359*
  Abstract - Full document (Acrobat PDF, 924 KBytes)

- Raul Silaghi, Alfred Strohmeier, Jörg Kienzle
  Porting OMTTs to CORBA
  2003-09-17 09:48:00 - *Publication's ID:200358*
  Abstract - Full document (Acrobat PDF, 250 KBytes)

- Raul Silaghi and Alfred Strohmeier
  Integrating CBSE, SoC, MDA, and AOP in a Software Development Method
  2003-09-17 09:43:56 - *Publication's ID:200357*
  Abstract - Full document (Acrobat PDF, 155 KBytes)

- Xavier Defago, André Schiper et Peter Urban
  Total Order Broadcast and Multicast Algorithms: Taxonomy and Survey
  2003-09-17 09:24:31 - *Publication's ID:200356*
  Abstract - Full document (Acrobat PDF, 509 KBytes)

- Naouel Ben Salem, Levente Buttyan, Jean-Pierre Hubaux and Markus Jakobsson
  Cooperation in Multi-hop Cellular Networks
  2003-09-17 09:09:27 - *Publication's ID:200355*
  Abstract - Full document (Acrobat PDF, 282 KBytes)

- Ronald SCHROETER, Nastaran FATEMI, Omar ABOU KHALED
  User oriented query language for MPEG-7 and MPEG-7 API.
  2003-09-11 14:39:18 - *Publication's ID:200354*
  Abstract

- A. Kupsys, S. Pleisch, A. Schiper, M. Wiesmann
  Towards JMS-Compliant Group Communication
  2003-09-04 14:40:59 - *Publication's ID:200353*
  Abstract - Full document (Acrobat PDF, 290 KBytes)

- Shane Sendall and Wojtek Kozaczynski
  Model Transformation the Heart and Soul of Model-Driven Software Development
  2003-07-31 11:07:44 - *Publication's ID:200352*
  Abstract - Full document (Acrobat PDF, 183 KBytes)

- Shane Sendall, Gilles Perrouin, Nicolas Guelfi, Olivier Biberstein
  Supporting Model-to-Model Transformations: The VMT Approach
  2003-07-31 11:04:27 - *Publication's ID:200351*
  Abstract - Full document (Acrobat PDF, 294 KBytes)

- Sonja Buchegger and Jean-Yves Le Boudec
  A Robust Reputation System for Mobile Ad-hoc Networks
  2003-07-28 14:45:34 - *Publication's ID:200350*
  Abstract - Full document (Acrobat PDF, 273 KBytes)

- Carole Delporte-Gallet, Hugues Fauconnier, Rachid Guerraoui, Bastian Pochon
  Distributed Programming for Dummies: A Shifting Transformation Technique
  2003-07-07 17:01:02 - *Publication's ID:200349*
  Abstract - Full document (Acrobat PDF, 326 KBytes)

- Authors: Rachid Guerraoui and Petr Kouznetsov
  On Failure Detectors and Type Boosters
  2003-07-04 15:18:16 - *Publication's ID:200348*
  Abstract - Full document (Acrobat PDF, 246 KBytes)

- Rachid Guerraoui and Petr Kouznetsov
  The Weakest Failure Detector for Non-Blocking Atomic Commit
  2003-07-04 15:16:30 - *Publication's ID:200347*
  Abstract - Full document (Acrobat PDF, 264 KBytes)

- Carlos Eisenberg and Boi Faltings
  Using the Breakout Algorithm to Identify Hard and Unsolvable Subproblems

2003-07-04 14:40:45 - *Publication's ID:200346*
Abstract - Full document (Acrobat PDF, 259 KBytes)

- Bozidar Radunovic and Jean-Yves Le Boudec
  Rate Performance Objectives of Multi-hop Wireless Networks
  2003-06-27 09:15:32 - *Publication's ID:200345*
  Abstract - Full document (Acrobat PDF, 207 KBytes)

- Andrey Naumenko, Alain Wegmann
  Triune Continuum Paradigm and Problems of UML Semantics
  2003-06-25 09:36:34 - *Publication's ID:200344*
  Abstract - Full document (Acrobat PDF, 289 KBytes)

- Andrey Naumenko, Alain Wegmann and Colin Atkinson
  The Role of Tarski's Declarative Semantics in the Design of Modeling Languages
  2003-06-25 09:32:38 - *Publication's ID:200343*
  Abstract - Full document (Acrobat PDF, 293 KBytes)

- Authors: Karl Aberer, Philippe Cudré-Mauroux, Manfred Hauswirth
  Start making sense: The Chatty Web approach for global semantic agreements
  2003-06-19 14:53:51 - *Publication's ID:200342*
  Abstract - Full document (Acrobat PDF, 285 KBytes)

- Patrick Th. Eugster
  Probabilistic Guarantees and Algorithms for Ad Hoc Networks
  2003-06-13 09:14:34 - *Publication's ID:200341*
  Abstract

- Henri Dubois-Ferriere, Matthias Grossglauser, Martin Vetterli
  Generalized Route Establishment Protocol (GREP): Proof of Loop-Free Operation
  2003-06-13 09:08:04 - *Publication's ID:200340*
  Abstract - Full document (Acrobat PDF, 98 KBytes)

- Richard Ekwall and André Schiper
  Revisiting Token-based Atomic Broadcast Algorithms
  2003-06-12 11:11:30 - *Publication's ID:200339*
  Abstract

- Felix C. Gaertner
  A Survey of Self-Stabilizing Spanning-Tree Construction Algorithms
  2003-06-10 14:29:52 - *Publication's ID:200338*
  Abstract - Full document (Acrobat PDF, 142 KBytes)

- Thomas Baar
  The Definition of Transitive Closure with OCL - Limitations and applications
  2003-06-03 11:24:52 - *Publication's ID:200337*
  Abstract

- Manfred Hauswirth, Anwitaman Datta, Karl Aberer
  Efficient, self-contained handling of identity in Peer-to-Peer systems
  2003-05-31 18:32:31 - *Publication's ID:200336*
  Abstract - Full document (Acrobat PDF, 269 KBytes)

- Jun Luo, Patrick Th. Eugster, and Jean-Pierre Hubaux
  PROSE: Lightweight Probabilistic Group Communication System for Mobile Ad Hoc Networks
  2003-05-26 16:58:22 - *Publication's ID:200335*
  Abstract - Full document (Acrobat PDF, 619 KBytes)

- Johannes Borgström and Uwe Nestmann
  On Bisimulations for the Spi Calculus
  2003-05-23 09:30:19 - *Publication's ID:200334*
  Abstract - Full document (Acrobat PDF, 475 KBytes)

- Mark Felegyhazi, Jean-Pierre Hubaux, Levente Buttyan
  Equilibrium Analysis of Packet Forwarding Strategies in Wireless Ad Hoc Networks - the Static Case (extended version)
  2003-05-22 15:01:35 - *Publication's ID:200333*
  Abstract - Full document (Acrobat PDF, 166 KBytes)

- Karl Aberer, Anwitaman Datta, Manfred Hauswirth
  The Quest for Balancing Peer Load in Structured Peer-to-Peer Systems

2003-05-22 14:52:25 - *Publication's ID:200332*
Abstract

- Sonja Buchegger and Jean Yves Le Boudec
**Coping with False Accusations in Misbehavior Reputation Systems for Mobile
Ad-hoc Networks.**
2003-05-20 11:36:45 - *Publication's ID:200331*
Abstract - Full document (Acrobat PDF, 188 KBytes)

- Ljubica Blazevic, Jean-Yves Le Boudec and Silvia Giordano
A Location Based Routing Method for Irregular Mobile Ad Hoc Networks
2003-05-20 11:00:42 - *Publication's ID:200330*
Abstract - Full document (Acrobat PDF, 977 KBytes)

- David CAVIN, Yoav SASSON, Andre SCHIPER
From a Location Service to a Multicast Service for Wireless Mobile Adhoc Networks
2003-05-08 14:44:40 - *Publication's ID:200329*
Abstract

- Rodrigo García García, Esther Gelle and Alfred Strohmeier
A Software Architecture for Industrial Automation
2003-04-25 11:08:54 - *Publication's ID:200328*
Abstract - Full document (Acrobat PDF, 294 KBytes)

- André Schiper
Dynamic Group Communication
2003-04-22 10:20:05 - *Publication's ID:200327*
Abstract - Full document (Acrobat PDF, 186 KBytes)

- Andrew P. Black, Vincent Cremet, Rachid Guerraoui, Martin Odersky
An Equational Theory for Transactions
2003-04-16 16:21:47 - *Publication's ID:200326*
Abstract - Full document (Acrobat PDF, 247 KBytes)

- Karl Aberer, Anwitaman Datta, Manfred Hauswirth
Identifying peers using a self-contained directory
2003-04-11 19:07:04 - *Publication's ID:200325*
Abstract - Full document (Acrobat PDF, 71 KBytes)

- Partha Dutta, Rachid Guerraoui and Bastian Pochon
Early Local Decisions in Distributed Agreement
2003-04-08 16:56:58 - *Publication's ID:200324*
Abstract - Full document (Acrobat PDF, 428 KBytes)

- Felix C. Gaertner, Arshad Jhumka
**Automating the Addition of Fail-Safe Fault-Tolerance: Beyond Fusion-Closed
Specifications**
2003-04-08 13:25:51 - *Publication's ID:200323*
Abstract - Full document (Acrobat PDF, 170 KBytes)

- David Cavin, Yoav Sasson and André Schiper
FRANC: A Lightweight Java Framework for Wireless Multihop Communication
2003-04-07 16:30:43 - *Publication's ID:200322*
Abstract - Full document (Acrobat PDF, 209 KBytes)

- Pascal Junod
On the Optimality of Linear, Differential and Sequential Distinguishers
2003-04-07 16:27:17 - *Publication's ID:200321*
Abstract - Full document (Acrobat PDF, 288 KBytes)

- Felix C. Gaertner
Byzantine Failures and Security: Arbitrary is not (always) Random
2003-04-07 09:02:53 - *Publication's ID:200320*
Abstract - Full document (Acrobat PDF, 811 KBytes)

- Henri Dubois-Ferriere
to be announced
2003-03-31 16:10:16 - *Publication's ID:200319*
Abstract

- Matthias Wiesmann and André Schiper
Beyond 1-Safety and 2-Safety for replicated databases: Group-Safety

2003-03-25 15:00:37 - *Publication's ID:200318*
Abstract

- Patrick Th. Eugster
Dynamic Proxies for Classes: Towards Type-Safe and Decoupled Remote Object Interaction
2003-03-21 16:52:22 - *Publication's ID:200317*
Abstract - Full document (Acrobat PDF, 667 KBytes)

- Prasenjit Dey and Anwitaman Datta
On Optimal Update Policies and Cluster Sizes for 2-Tier Distributed Systems
2003-03-21 15:07:22 - *Publication's ID:200316*
Abstract

- Péter Urbán and Ilya Shnayderman and André Schiper
Comparison of Failure Detectors and Group Membership: Performance Study of Two Atomic Broadcast Algorithms (extended version)
2003-03-19 18:00:51 - *Publication's ID:200315*
Abstract - Full document (Acrobat PDF, 234 KBytes)

- Didier Buchs, Stanislav Chachkov, David Hürzeler
Modelling a Secure, Mobile, and Transactional System with CO-OPN
2003-03-19 10:12:23 - *Publication's ID:200314*
Abstract - Full document (Acrobat PDF, 245 KBytes)

- Karl Aberer, Philippe Cudré-Mauroux, Anwitaman Datta, Manfred Hauswirth
Title: PIX-Grid: A Platform for P2P Photo Exchange
2003-03-17 15:21:37 - *Publication's ID:200313*
Abstract

- Michael Gastpar, Pier Luigi Dragotti, Martin Vetterli
The distributed Karhunen-Loeve transform
2003-03-11 19:25:18 - *Publication's ID:200312*
Abstract - Full document (Acrobat PDF, 241 KBytes)

- Ludger Fiege, Felix Gaertner, Oliver Kasten, Andreas Zeidler
Supporting Mobility in Content-Based Publish/Subscribe Middleware
2003-03-07 11:11:57 - *Publication's ID:200311*
Abstract

- Bozidar Radunovic, Jean-Yves Le Boudec
Why Max-min Fairness Is Not Suitable For Multi-Hop Wireless Networks
2003-03-03 10:30:35 - *Publication's ID:200310*
Abstract - Full document (Acrobat PDF, 138 KBytes)

- Stefan Pleisch, Arnas Kupsys, André Schiper
Replicated Invocation
2003-02-19 10:16:57 - *Publication's ID:200309*
Abstract - Full document (Acrobat PDF, 171 KBytes)

- Sébastien Baehni, Patrick Th. Eugster, Rachid Guerraoui, Philippe Altherr
Pragmatic Type Interoperability
2003-02-19 09:22:55 - *Publication's ID:200308*
Abstract - Full document (Acrobat PDF, 589 KBytes)

- Henri Dubois-Ferriere, Matthias Grossglauser, Martin Vetterli
Age Matters: Efficient Route Discovery in Mobile Ad Hoc Networks Using Encounter Ages
2003-02-12 15:07:52 - *Publication's ID:200307*
Abstract

- Anwitaman Datta, Manfred Hauswirth, Karl Aberer
Beyond "web of trust": Enabling P2P E-commerce
2003-02-04 11:53:32 - *Publication's ID:200306*
Abstract

- Péter Urbán and Ilya Shnayderman and André Schiper
Comparison of Failure Detectors and Group Membership: Performance Study of Two Atomic Broadcast Algorithms
2003-01-28 10:50:54 - *Publication's ID:200305*
Abstract - Full document (Acrobat PDF, 138 KBytes)

- Andrea Ridolfi, Jérôme Idier
  Penalized Maximum Likelihood Estimation for Normal Mixture Distributions
  2003-01-24 09:41:52 - *Publication's ID:200304*
  Abstract - Full document (Acrobat PDF, 323 KBytes)

- Patrick Th. Eugster
  Atomic Probabilistic Broadcast
  2003-01-21 13:18:46 - *Publication's ID:200303*
  Abstract

- David ALLEYSSON, Sabine SÜSSTRUNK, and Jeanny HÉRAULT
  Accurate Color Demosaicing inspired by the Human Visual System
  2003-01-15 16:30:10 - *Publication's ID:200302*
  Abstract

- Sergio Mena, André Schiper, Pawel Wojciechowski
  A Step Towards a New Generation of Group Communication Systems
  2003-01-14 18:13:18 - *Publication's ID:200301*
  Abstract - Full document (Acrobat PDF, 179 KBytes)

- Andrea Ridolfi, Irena Maravic, Julius Kusuma, Martin Vetterli
  Sampling signals with finite rate of innovation: the noisy case
  2002-12-23 13:46:33 - *Publication's ID:200285*
  Abstract - Full document (Acrobat PDF, 79 KBytes)

- Bozidar Radunovic, Jean-Yves Le Boudec
  Joint Scheduling, Power Control and Routing in Symmetric, One-dimensional, Multi-hop Wireless Networks
  2002-12-19 13:49:19 - *Publication's ID:200284*
  Abstract - Full document (Acrobat PDF, 171 KBytes)

- Shane Sendall
  Gauging the Quality of Examples for Teaching Design Patterns
  2002-12-18 13:35:18 - *Publication's ID:200283*
  Abstract - Full document (Acrobat PDF, 39 KBytes)

- Joerg Widmer, Catherine Boutremans, Jean-Yves Le Boudec
  End-to-end Congestion Control for Flows with Variable Packet Size
  2002-12-17 17:09:06 - *Publication's ID:200282*
  Abstract - Full document (Acrobat PDF, 337 KBytes)

- Milan Vojnovic, Jean-Yves Le Boudec, Don Towsley, and Vishal Misra
  A Note on the Stochastic Bias of Some Increase-Decrease Congestion Controls: HighSpeed TCP Case Study
  2002-11-29 11:41:46 - *Publication's ID:200281*
  Abstract - Full document (Acrobat PDF, 429 KBytes)

- Pierre Brémaud, Laurent Massoulié, Andrea Ridolfi
  Power spectra of random spike fields and related processes
  2002-12-09 09:03:58 - *Publication's ID:200280*
  Abstract - Full document (Acrobat PDF, 255 KBytes)

- Karl Aberer
  Efficient Search in Unbalanced, Randomized Peer-To-Peer Search Trees
  2002-11-21 15:30:45 - *Publication's ID:200279*
  Abstract

- Felix Gaertner
  Revisiting Liveness Properties in the Context of Secure Systems
  2002-11-20 19:23:55 - *Publication's ID:200278*
  Abstract - Full document (Acrobat PDF, 176 KBytes)

- Ion Constantinescu, Boi Faltings
  Efficient Matchmaking and Directory Services
  2002-11-18 11:54:48 - *Publication's ID:200277*
  Abstract - Full document (Acrobat PDF, 357 KBytes)

- Karl Aberer, Philippe Cudré-Mauroux, Manfred Hauswirth
  The Chatty Web: Emergent Semantics through Gossiping
  2002-11-15 17:26:40 - *Publication's ID:200276*
  Abstract

- Alain Wegmann
  Theory and Practice of a Course Integrating Business and Information Technology
  2002-11-05 17:14:12 - *Publication's ID:200275*
  Abstract

- Karl Aberer, Manfred Hauswirth, Magdalena Punceva
  Self-organized construction of distributed access structures: A comparative evaluation of P-Grid and FreeNet
  2002-11-01 14:46:17 - *Publication's ID:200274*
  Abstract

- Karl Aberer, Philippe Cudré-Mauroux, Anwitaman Datta, Zoran Despotovic, Manfred Hauswirth, Magdalena Punceva, Roman Schmidt, Jie Wu
  Advanced Peer-to-Peer Networking: The P-Grid System and its Applications
  2002-10-31 10:32:31 - *Publication's ID:200273*
  Abstract

- Massimo Merro, Josva Kleist, and Uwe Nestmann
  Mobile Objects as Mobile Processes
  2002-10-29 17:48:11 - *Publication's ID:200272*
  Abstract - Full document (Acrobat PDF, 699 KBytes)

- Roman Schmidt
  Gridella: an open and efficient Gnutella-compatible Peer-to-Peer System based on the P-Grid approach

  2002-10-10 17:21:23 - *Publication's ID:200271*
  Abstract

- Martin Odersky, Vincent Cremet, Christine Roeckl, Matthias Zenger
  A Nominal Theory of Objects with Dependent Types
  2002-09-30 17:16:50 - *Publication's ID:200270*
  Abstract - Full document (Acrobat PDF, 561 KBytes)

- Raul Silaghi and Alfred Strohmeier
  Critical Evaluation of the EJB Transaction Model
  2002-09-30 11:55:04 - *Publication's ID:200269*
  Abstract - Full document (Acrobat PDF, 177 KBytes)

- Ljubica Blazevic, Jean-Yves Le Boudec and Silvia Giordano
  A Scalable Routing Method for Irregular Mobile Ad Hoc Networks
  2002-09-30 11:27:09 - *Publication's ID:200268*
  Abstract - Full document (Acrobat PDF, 371 KBytes)

- Manfred Hauswirth, Anwitaman Datta, Karl Aberer
  Handling Identity in Peer-to-Peer Systems
  2002-09-30 11:12:07 - *Publication's ID:200267*
  Abstract

- Michael Gastpar and Martin Vetterli
  On the capacity of large Gaussian relay networks
  2002-09-30 10:57:48 - *Publication's ID:200266*
  Abstract

- Alain Wegmann
  The Systemic Enterprise Architecture Methodology (SEAM). Business and IT Alignment for Competitiveness
  2002-09-27 11:30:22 - *Publication's ID:200265*
  Abstract - Full document (Acrobat PDF, 221 KBytes)

- Guy Genilloud, Alain Wegmann, William Franck
  Use Cases and Joint Actions in UML
  2002-09-27 11:23:48 - *Publication's ID:200264*
  Abstract

- Arshad Jhumka, Felix C. Gärtner, Christof Fetzer, Neeraj Suri
  On Systematic Design of Fast and Perfect Detectors
  2002-09-22 10:25:25 - *Publication's ID:200263*
  Abstract - Full document (Acrobat PDF, 198 KBytes)

- Matthew Andrews, Bell Laboratories, and Milan Vojnovic, EPFL

Scheduling Reserved Traffic in Input-Queued Switches: New
Delay Bounds via Probabilistic Techniques
2002-09-02 10:00:45 - *Publication's ID:200262*
Abstract - Full document (Acrobat PDF, 356 KBytes)

- Naohiro Hayashibara, Péter Urbán, André Schiper, Takuya Katayama
Performance Comparison Between the Paxos and Chandra-Toueg Consensus
Algorithms
2002-08-30 08:14:30 - *Publication's ID:200261*
Abstract - Full document (Acrobat PDF, 103 KBytes)

- Matthias Grossglauser, AT&T Research Laboratories, and Martin Vetterli, EPFL
Locating Nodes with EASE: Mobility Diffusion of Last Encounters in Ad Hoc
Networks
2002-08-29 14:10:19 - *Publication's ID:200260*
Abstract

- Mohamed M. Kandé, Valentin Crettaz, Alfred Strohmeier, Shane Sendall
Bridging the Gap between IEEE 1471, Architecture Description Languages and UML
2002-08-26 11:42:29 - *Publication's ID:200259*
Abstract - Full document (Acrobat PDF, 302 KBytes)

- Mohamed M. Kandé, Jörg Kienzle and Alfred Strohmeier
From AOP to UML: Towards an Aspect-Oriented Architectural Modeling Approach
2002-08-26 11:40:35 - *Publication's ID:200258*
Abstract - Full document (Acrobat PDF, 174 KBytes)

- Philipp H. Oser, Christian Gasser, Daniel Gorostidi and Rachid Guerraoui
The LEAF Platform: Incremental Enhancements for the J2EE
2002-08-26 11:33:59 - *Publication's ID:200257*
Abstract - Full document (Acrobat PDF, 433 KBytes)

- David Cavin, Yoav Sasson and André Schiper
On the Accuracy of MANET Simulators
2002-08-26 11:11:33 - *Publication's ID:200256*
Abstract

- Marius Calin Silaghi
On solving distributed CS(O)Ps with privacy
2002-07-24 09:17:35 - *Publication's ID:200255*
Abstract - Full document (Acrobat PDF, 193 KBytes)

- Yoav SASSON, David CAVIN, André SCHIPER
Probabilistic Broadcast for Flooding in Wireless Mobile Ad hoc Networks
2002-07-24 09:15:46 - *Publication's ID:200254*
Abstract - Full document (Acrobat PDF, 104 KBytes)

- Fernando Pedone, Nelson L. Duarte and Mario Goulart
Probabilistic Queries in Large-Scale Networks
2002-07-12 08:11:14 - *Publication's ID:200253*
Abstract - Full document (Acrobat PDF, 351 KBytes)

- Svend Frolund and Fernando Pedone
Ruminations on Domain-Based Reliable Broadcast
2002-07-12 08:10:19 - *Publication's ID:200252*
Abstract - Full document (Acrobat PDF, 269 KBytes)

- Pascal Felber and Fernando Pedone
Probabilistic Atomic Broadcast
2002-07-12 08:08:58 - *Publication's ID:200251*
Abstract - Full document (Acrobat PDF, 294 KBytes)

- Jun Luo, Patrick Th. Eugster, and Jean-Pierre Hubaux
Route Driven Gossip: Probabilistic Reliable Multicast in Ad Hoc Networks
2002-07-12 08:06:31 - *Publication's ID:200250*
Abstract - Full document (Acrobat PDF, 213 KBytes)

- Jean Monnerat
Computation of the discrete logarithm on elliptic curves of trace one
2002-07-10 07:55:19 - *Publication's ID:200249*
Abstract - Full document (Acrobat PDF, 172 KBytes)

- Bozidar Radunovic, Jean-Yves Le Boudec
  A Unified Framework for Max-Min and Min-Max Fairness with Applications
  2002-07-05 10:08:12 - *Publication's ID:200248*
  Abstract - Full document (Acrobat PDF, 150 KBytes)

- Anwitaman Datta, Manfred Hauswirth, Karl Aberer
  Updates in Highly Unreliable, Replicated Peer-to-Peer Systems
  2002-07-04 07:54:35 - *Publication's ID:200247*
  Abstract - Full document (Acrobat PDF, 282 KBytes)

- Ion Constantinescu, Steven Willmott, Monique Calisti
  Enterprise Java Beans, Distributed Artificial Intelligence and Group Communication
  2002-07-04 07:52:17 - *Publication's ID:200246*
  Abstract - Full document (Acrobat PDF, 248 KBytes)

- Karl Aberer
  Scalable Data Access in Peer-to-Peer Systems Using Unbalanced Search Trees
  2002-07-01 13:47:37 - *Publication's ID:200245*
  Abstract - Full document (Acrobat PDF, 529 KBytes)

- Phil Bagwell
  Fast Functional Lists, Hash-Lists, Deques and Variable Length Arrays
  2002-07-01 08:47:30 - *Publication's ID:200244*
  Abstract - Full document (Acrobat PDF, 224 KBytes)

- Didier Buchs, Sandro Costa, David Hurzeler
  Flexibler Subtyping Relations for Component-Oriented Formalisms
  2002-06-12 08:45:08 - *Publication's ID:200243*
  Abstract - Full document (Acrobat PDF, 369 KBytes)

- Steven Willmott, Monique Calisti, Emma Rollon
  Challenges in Large-Scale Open Agent Mediated Economies
  2002-06-12 08:39:13 - *Publication's ID:200242*
  Abstract - Full document (Acrobat PDF, 174 KBytes)

- Steven Willmott, Matteo Somacher, Ion Constantinescu, Jonathan Dale, Stefan Poslad,
  David Bonnefoy, Jerome Picault, Juan Jim Tan
  The Agentcities Network Architecture
  2002-06-12 08:37:56 - *Publication's ID:200241*
  Abstract - Full document (Acrobat PDF, 39 KBytes)

- Steven Willmott, Jonathan Dale, Patricia Charlton
  Agent Communication Semantics for Open Environments: Issues and Challenges
  2002-06-12 08:36:22 - *Publication's ID:200240*
  Abstract - Full document (Acrobat PDF, 178 KBytes)

- Florian Bois
  Specifying Design Patterns in OOAD
  2002-06-07 14:33:03 - *Publication's ID:200239*
  Abstract - Full document (Acrobat PDF, 849 KBytes)

- Pavel Balabko, Alain Wegmann
  The Role of Synthesis Constraints in Role Modeling
  2002-06-07 14:32:06 - *Publication's ID:200238*
  Abstract - Full document (Acrobat PDF, 204 KBytes)

- Pavel Balabko, Hien Dat TRAN, Alain Wegmann
  StreamCom: Business Analysis and System Design Specification
  2002-01-07 14:30:37 - *Publication's ID:200237*
  Abstract - Full document (Acrobat PDF, 1493 KBytes)

- Michael Gastpar
  The Wyner-Ziv Problem with Multiple Sources
  2002-06-06 08:53:22 - *Publication's ID:200236*
  Abstract - Full document (Acrobat PDF, 231 KBytes)

- Catherine Boutremans and Jean-Yves Le Boudec
  Adaptive joint playout buffer and FEC adjustement for Internet Telephony
  2002-05-29 15:35:20 - *Publication's ID:200235*
  Abstract - Full document (Acrobat PDF, 491 KBytes)

- Srdjan Capkun, Levente Buttyan and Jean-Pierre Hubaux

Self-Organized Public-Key Management for Mobile Ad Hoc Networks
2002-05-28 12:03:32 - *Publication's ID:200234*
Abstract - Full document (Acrobat PDF, 174 KBytes)

- Luis Botelho, Steven Willmott, Tianning Zhang, Jonathan Dale
  Review of Content Languages Suitable for Agent-Agent Communication
  2002-05-27 14:28:45 - *Publication's ID:200233*
  Abstract - Full document (Acrobat PDF, 304 KBytes)

- Partha Dutta and Rachid Guerraoui
  Fast Indulgent Consensus with Zero Degradation
  2002-05-22 14:48:05 - *Publication's ID:200232*
  Abstract - Full document (Acrobat PDF, 361 KBytes)

- Partha Dutta and Rachid Guerraoui
  The Inherent Price of Indulgence
  2002-05-22 14:47:03 - *Publication's ID:200231*
  Abstract - Full document (Acrobat PDF, 297 KBytes)

- C. Delporte-Gallet, H. Fauconnier, and R. Guerraoui
  Failure Detection Lower Bounds on Registers and Consensus
  (Preliminary Version)
  2002-05-22 14:46:01 - *Publication's ID:200230*
  Abstract - Full document (Acrobat PDF, 304 KBytes)

- C. Delporte-Gallet, H. Fauconnier, R. Guerraoui
  A Realistic Look at Failure Detectors
  2002-05-22 14:45:14 - *Publication's ID:200229*
  Abstract - Full document (Acrobat PDF, 208 KBytes)

- Partha Dutta, Svend Frolund, Rachid Guerraoui, Bastian
  Pochon
  An Efficient Universal Construction for Message-Passing
  Systems
  2002-05-22 14:44:01 - *Publication's ID:200228*
  Abstract - Full document (Acrobat PDF, 381 KBytes)

- Carole Delporte-Gallet, Hugues Fauconnier, Rachid Guerraoui,
  and Petr Kouznetsov
  Mutual Exclusion in Asynchronous Systems with Failure
  Detectors
  2002-05-22 14:42:54 - *Publication's ID:200227*
  Abstract - Full document (Acrobat PDF, 264 KBytes)

- Rachid Guerraoui and Petr Kouznetsov
  On the Weakest Failure Detector for Non-Blocking Atomic Commit.
  2002-05-22 14:41:49 - *Publication's ID:200226*
  Abstract - Full document (Acrobat PDF, 255 KBytes)

- P. Th. Eugster, P. Felber, R. Guerraoui, S. B. Handurukande
  Event Systems : How to Have Your Cake and Eat It Too
  2002-05-22 14:40:34 - *Publication's ID:200225*
  Abstract

- Ion Constantinescu, Boi Faltings
  Behavioural Description Formalisms for Service Integration - Survey and
  Comparation
  2002-05-22 14:37:39 - *Publication's ID:200224*
  Abstract - Full document (Acrobat PDF, 277 KBytes)

- Srdjan Capkun, Levente Buttyan and Jean-Pierre Hubaux
  Small Worlds in Security Systems: an Analysis of the PGP Certificate Graph
  2002-05-21 09:31:58 - *Publication's ID:200223*
  Abstract

- Milan Vojnovic and Jean-Yves Le Boudec
  Stochastic Bound on Delay for Guaranteed Rate Nodes
  2002-05-21 09:24:48 - *Publication's ID:200222*
  Abstract - Full document (Acrobat PDF, 84 KBytes)

- Mario Cagalj, Jean-Pierre Hubaux and Christian Enz
  Minimum-energy broadcast in all-wireless networks:

NP-Completeness and distribution issues
2002-05-07 08:57:51 - *Publication's ID:200221*
Abstract - Full document (Acrobat PDF, 263 KBytes)

- Bernadette Charron-Bost, Xavier Defago, André Schiper
  Broadcasting Messages in Fault-Tolerant Distributed Systems: the benefit of handling input-triggered and output-triggered suspicions differently
  2002-05-03 08:50:53 - *Publication's ID:200220*
  Abstract - Full document (Acrobat PDF, 101 KBytes)

- Zoran Despotovic, Karl Aberer
  Trust-Aware Delivery of Composite Goods
  2002-04-29 08:49:50 - *Publication's ID:200219*
  Abstract - Full document (Acrobat PDF, 207 KBytes)

- Irena Maravic, Martin Vetterli
  Digital DS-CDMA receiver working below the chip rate: theory and design
  2002-04-29 08:47:28 - *Publication's ID:200218*
  Abstract - Full document (Acrobat PDF, 547 KBytes)

- Vicent Cholvi, Juan Echague and Jean-Yves Le Boudec
  Worst Case Burstiness Increase due to FIFO Multiplexing
  2002-04-19 14:52:26 - *Publication's ID:200217*
  Abstract - Full document (Acrobat PDF, 131 KBytes)

- Jörg Kienzle and Rachid Guerraoui
  AOP: Does it Make Sense ? The Case of Concurrency and Failures
  2002-04-12 14:12:19 - *Publication's ID:200216*
  Abstract - Full document (Acrobat PDF, 560 KBytes)

- Catherine Boutremans, Gianluca Iannaccone, Christophe Diot
  Impact of link failure on VoIP performance
  2002-04-09 08:51:14 - *Publication's ID:200215*
  Abstract - Full document (Acrobat PDF, 168 KBytes)

- Matthias Zenger
  Type-Safe Prototype-Based Component Evolution
  2002-04-09 08:48:13 - *Publication's ID:200214*
  Abstract - Full document (Acrobat PDF, 296 KBytes)

- Gil Regev, Alain Wegmann
  UML for Early Requirements Elicitation: A Regulation based Approach
  2002-04-09 08:46:13 - *Publication's ID:200213*
  Abstract - Full document (Acrobat PDF, 234 KBytes)

- Andrey Naumenko, Alain Wegmann
  Formal Foundations of General System Modeling
  2002-03-25 10:43:09 - *Publication's ID:200212*
  Abstract - Full document (Acrobat PDF, 387 KBytes)

- Andrey Naumenko, Alain Wegmann
  A metamodel for the Unified Modeling Language: critical analysis and solution
  2002-03-25 10:40:18 - *Publication's ID:200211*
  Abstract - Full document (Acrobat PDF, 295 KBytes)

- Fernando Pedone, André Schiper, Peter Urban, David Cavin
  Solving Agreement Problems with Weak Ordering Oracles
  2002-03-12 15:57:11 - *Publication's ID:200210*
  Abstract - Full document (Acrobat PDF, 253 KBytes)

- Jörg Kienzle, Alfred Strohmeier, Alexander Romanovsky
  Auction System Design Using Open Multithreaded Transactions
  2002-02-13 00:00:00 - *Publication's ID:200209*
  Abstract - Full document (Acrobat PDF, 153 KBytes)

- Rodrigo Garcia Garcia, Alfred Strohmeier
  Experience Report on the Implementation of Extensible Protected Types for GNAT
  2002-02-13 00:00:00 - *Publication's ID:200208*
  Abstract - Full document (Acrobat PDF, 33 KBytes)

- Xavier Défago, André Schiper
  Specification of Replication Techniques, Semi-Passive Replication, and Lazy

consensus*
2002-02-11 00:00:00 - *Publication's ID:200207*
Abstract - Full document (Acrobat PDF, 218 KBytes)

- Milan Vojnovic and Jean-Yves Le Boudec
  On the Long-Run Behavior of Equation-Based Rate Control
  2002-02-04 00:00:00 - *Publication's ID:200206*
  Abstract - Full document (Acrobat PDF, 1084 KBytes)

- Lukas Kencl (IBM Zurich), Bozidar Radunovic (LCA)
  A General Method for Finding the Most Economical Distributed Router Architecture
  2002-02-04 00:00:00 - *Publication's ID:200205*
  Abstract - Full document (Acrobat PDF, 627 KBytes)

- Sébastien Baehni, Patrick Th. Eugster, Rachid Guerraoui
  OS Support for P2P Programming: a Case for TPS
  2002-02-04 00:00:00 - *Publication's ID:200204*
  Abstract - Full document (Acrobat PDF, 414 KBytes)

- Lucian Prodan, Daniel Mange, Gianluca Tempesti
  The Embryonics Project: Specifications of the Muxtree Fields Programmable Gate Array
  2002-01-28 00:00:00 - *Publication's ID:200203*
  Abstract - Full document (Acrobat PDF, 972 KBytes)

- Pawel T. Wojciechowski, Sergio Mena, André Schiper
  Semantics of Protocol Modules Composition and Interaction
  2002-01-21 00:00:00 - *Publication's ID:200202*
  Abstract - Full document (Acrobat PDF, 326 KBytes)

- Sonja Buchegger and Jean-Yves Le Boudec
  Performance Analysis of the CONFIDANT Protocol. Cooperation Of Nodes - Fairness In Dynamic Ad-hoc NeTworks.
  2002-01-21 00:00:00 - *Publication's ID:200201*
  Abstract - Full document (Acrobat PDF, 166 KBytes)